FEDERAL FACILITIES COMPLIANCE AGREEMENT/COMPLIANCE ORDER

TREATMENT REPORT No. 1

FINAL REPORT

PROCESS TECHNOLOGY DEVELOPMENT

December 1989

A. F. Sferrazza
Program Manager

ROCKWELL INTERNATIONAL
Aerospace Operations
Rocky Flats Plant
P. O. Box 464
Golden, Colorado 90402-0464

U. S. Department of Energy
Contract DE-AC04-76DP03533

ACKNOWLEDGEMENTS

This report is the result of the work of many individuals. Each group with the Rockwell International Rocky Flats Process Technology Development Department had one or more representatives involved in the report preparation. These groups are Pyrochemical Technology, Chemical Technology, Product Physical Chemistry, Equipment Design and Development, Materials Development, Process Instrumentation and Control, and Nuclear Instrumentation and Control.

Other Rockwell Rocky Flats organizations involved were the Waste Process Engineering Group, the Waste Compliance and Planning Group, the Waste Process Support Group, the Waste Operations Department, the RCRA/CERCLA Office, and the Legal Department.

The BDM Corporation, a contractor to the Department of Energy Headquarters, was instrumental in preparing the information on the DOE waste treatment facilities. Other contributors include DOE, the External Review Board Members, and Los Alamos National Laboratory.

LIST OF ACRONYMS

AEA	Atomic Energy Act
BDAT	Best Demonstrated Available Technology (EPA)
CERCLA	Comprehensive Environmental Response Compensation and Liability Act
CCWE	Constituent Concentrations in the Waste Extract
CFR	Code of Federal Regulations
CIF	Consolidated Incineration Facility
DOE	U. S. Department of Energy
DOT	U. S. Department of Transportation
DWPF	Defense Waste Processing Facility
EP	Extractive Procedure (Tests)
EPA	U. S. Environmental Protection Agency
ETF	Effluent Treatment Facility
FBI	Fluidized Bed Incinerator
FFCA	Federal Facilities Compliance Agreement
GCD	Greater Confinement Disposal
HEPA	High Efficiency Particulate Air (Filter)
HLW	High Level Waste
HOC	Hazardous Organic Compound
HSWA	Hazardous and Solid Waste Amendments to RCRA (1984)
HW	Hazardous Waste
INEL	Idaho National Engineering Laboratory
LANL	Los Alamos National Laboratory
LDR	Land Disposal Restrictions
LLNL	Lawrence Livermore National Laboratory
LLW	Low-Level Wastes
MW	Mixed Waste
MWMU	Mixed Waste Management Unit
MW	Mixed Wastes
NTS	Nevada Test Site
NWCF	New Waste Calcining Facility (INEL)
PCB	Polychlorinated Biphenyl
ppb	parts per billion

ppm	parts per million
PREPP	Process Experimental Pilot Plant
PTD	Process Technology Development (RFP)
PWI	Plutonium Waste Incinerator
RCRA	Resource Conservation Recovery Act
RD&D	Research, Development and Demonstration
RFP	Rocky Flats Plant
RMW	Radioactive Mixed Waste
RWMC	Radioactive Waste Management Complex
SLD	Shallow Land Disposal
SRS	Savannah River Site
TCLP	Toxic Characteristic Leaching Procedure (as described in 40 CFR 286)
TDF	Treatment Development Facility
THF	Tetrahydrofuran
TRU	Transuranic Wastes
TSCA	Toxic Substances Control Act
TWF	Transuranic Waste Facility
TWSTF	Transuranic Waste Storage and Treatment Facility
VOC	Volatile Organic Compound
WAC	Waste Acceptance Criteria
WED	Waste Experimental Development
WERF	Waste Experimental Reduction Facility (INEL)
WHPP	Waste Handling Pilot Plant
WIPP	Waste Isolation Pilot Plant
WPF	Waste Processing Facility

1.0 EXECUTIVE SUMMARY

This document has been prepared in response to a September 1989 agreement - the Federal Facilities Compliance Agreement (FFCA) - signed by the United States Environmental Protection Agency (EPA), the State of Colorado, and the United States Department of Energy (DOE). The purpose of the FFCA is to provide a one year period for DOE to achieve compliance at the Rocky Flats Plant (RFP) with the land disposal restrictions (LDR) of the Hazardous and Solid Waste Amendments of 1984 (HSWA), regulations found in 40 CFR Part 268, and applicable State law. At the end of this one year period, DOE must have achieved compliance with the LDR, or have reported and certified that all feasible alternatives for achieving compliance with the LDR have been fully explored and exhausted.

The FFCA requires generation of 11 major reports. This report, Treatment Report No.1, addresses 18 RFP mixed wastes containing both radioactive and hazardous components prohibited from storage and land disposal by the LDR. Mixed wastes include aqueous and organic sludges, liquid and solidified organics, combustibles, filters, metals, acids, polychlorinated biphenyls (PCBs), and miscellaneous. Most contain Resource Conservation and Recovery Act (RCRA)-listed volatile organic compounds (VOCs). Mixed wastes include both low-level wastes (LLW) and transuranic (TRU) mixed wastes. Treatment technologies will be the same whether the wastes are LLW or TRU. The technologies will either have to eliminate those constituents that make the waste "mixed," that is, convert the mixed waste to LLW or TRU, or meet LDR requirements to give mixed wastes that can be land disposed. At present, waste characterization is lacking, so much so that characterization will be required before treatment technologies can be chosen.

The report includes identification of treatment and disposal technologies and capacities; DOE and commercial treatment technologies and capacities available to treat these wastes; new or alternative DOE or commercial technologies under development, and an assessment of when available; and bases and assumptions used in forming the response and making the assessments.

The report only presents options to be considered. It does not provide a laid-out solution.

Technologies considered include thermal, chemical, physical, immobilization, and high-level waste solidification techniques. (RFP does not have high-level waste, but some of the solidification techniques might be beneficial, especially in decreasing waste form leachability.) Waste generation rates and backlogs, RCRA characteristics, treatment alternatives, and qualitative treatment evaluations are given. DOE facilities and capacities and new/alternative technologies in development are also discussed, where known. (Some additional information on DOE facilities and capacities will be available when DOE Headquarters issues the "National Report on Prohibited Waste and Treatment Options," on January 17, 1990.) No commercial facilities are available at the present time for treating mixed wastes. A proposed system for ranking technologies is also briefly presented; the actual ranking will be done in subsequent reports. Two rankings will be used, a "short term" one that will favor technologies and facilities now available to enable RFP to achieve compliance as soon as possible; and a "long term" one that will emphasize promising technologies able to reduce volume, decrease waste form leachability, treat different wastes (multiple use), etc.

Treatment Report No.1 does not include all the LDR wastes at RFP but only those identified in a previously issued Storage Report. A second report, Treatment Report No.2, will provide the same information as this Report for wastes not identified in the Storage Report and subsequently determined to be prohibited waste. The Treatment Reports will not include rankings of technologies proposed for individual wastes, nor will they address the resources required to evaluate/develop these technologies or the schedules. This will be done in Treatment Plans No.1 and No.2 for Treatment Reports No.1 and No.2, respectively.

In the time that was allowed an exhaustive review and analysis was made of technologies for waste treatment. This effort is not completed, however, and will continue as information is gathered for Treatment Plan No.1.

2.0 INTRODUCTION

This section will briefly discuss the background of the regulatory changes that have led to the current situation for mixed wastes (wastes containing both radioactive and hazardous materials) at DOE sites throughout the country. It will then address specifically the FFCA, an agreement that defines how the requirements imposed by the regulatory changes will be met at RFP.

2.1 Background (1)

In 1984, Congress enacted the HSWA to RCRA, including a prohibition on land disposal of hazardous wastes. The prohibition applies to all "characteristic" and "listed" hazardous wastes identified in 40 CFR Part 261. The prohibition occurs in phases, with various groups of wastes restricted from land disposal pursuant to statutory deadlines. The EPA set treatment requirements which, when achieved, render the wastes acceptable for land disposal.

The HSWA LDR are intended to eliminate or discourage the placement of untreated restricted hazardous wastes in land disposal units when a better treatment or destruction alternative exists. "Land disposal" is defined in RCRA to include any placement (for storage or disposal) in a landfill, surface impoundment, waste pile, injection well, land treatment facility, salt dome or salt formation, underground mine or cave, or concrete wall or bunker.

The first group of wastes prohibited from land disposal was solvents and dioxins. EPA issued regulations restricting the land disposal of these wastes on November 8, 1986. "California List" wastes (consisting primarily of liquids containing cyanides, heavy metals, polychlorinated biphenyls (PCBs), halogenated organic compounds, and acids) were restricted on July 8, 1987. EPA addressed the first third of all remaining hazardous wastes in restrictions effective August 8, 1988, the second third in restrictions effective June 8, 1989. Restrictions applicable to the third group become effective May

8, 1990. There is a new proposal to grant a two-year national capacity variance for radioactive mixed wastes. The EPA bases the proposed national capacity variance upon a determination that there is inadequate treatment capacity available for these wastes. (The same document also proposes many new regulations) (2).

LLW disposal at the Nevada Test Site (NTS) is by shallow-land burial, and TRU waste emplacement at the Waste Isolation Pilot Plant (WIPP) in New Mexico will occur at a depth of 655 meters in a bedded salt formation. Both facilities, therefore, employ land disposal as defined by RCRA. Portions of both LLW and TRU wastes contain hazardous wastes and are subject to LDR.

The application of RCRA and its amendments to hazardous wastes containing radioactive materials regulated by the Atomic Energy Act (AEA) initially caused considerable confusion. The DOE issued an interpretive rule on May 1, 1987, to clarify which mixed wastes were subject to RCRA regulations. The effect of the rule is that any matrix containing a RCRA hazardous and a radioactive waste subject to the AEA is a radioactive mixed waste subject to RCRA regulations, regardless of any further subclassification of the radioactive component as high-level, low-level, or transuranic. As a result, radioactive mixed waste is subject to dual regulation. The impact of EPA's LDR is to require any facility generating waste containing a restricted hazardous component to comply with the requirements of 40 CFR Part 268 regarding treatment before land disposal, record keeping, and reporting.

Prior to the May 1, 1987, ruling, much of this waste had been disposed in landfills designed and regulated by the DOE under the AEA for the disposal of low-level radioactive waste. (Disposal of low-level mixed waste had actually stopped at most DOE facilities before the official ruling.) This practice was officially halted until the disposal facilities could obtain the needed regulatory approvals to receive hazardous waste as required under RCRA. To a large extent this situation remains unchanged today; most DOE low-level radioactive waste disposal facilities have not yet obtained the necessary approvals to take mixed waste or have chosen not to make the attempt. The

exceptions to this have primarily been limited to disposal only of mixed waste generated in their own facility. This has left most of the DOE facilities in the mode of storing their mixed waste or treating the waste so that disposal as LLW or TRU waste can be accomplished.

2.2 Federal Facilities Compliance Agreement (3)

In September 1989 an agreement was signed by officials of EPA, the State of Colorado, and DOE. This agreement, the FFCA, provides a one year period for DOE to achieve compliance at RFP with the LDR and applicable State of Colorado law. This period of one year is given for DOE to "take all feasible steps to address and resolve alleged LDR violations at RFP that are covered by this Agreement." (The FFCA does not address RCRA compliance issues other than LDR.) At the end of the year, DOE shall have either achieved compliance with the LDR or reported and certified that all feasible alternatives for achieving compliance with the LDR have been "fully explored and exhausted."

The FFCA requires generation of 11 major reports: (1) a Storage Report, identifying and describing mixed wastes stored at RFP which DOE determines to be currently prohibited from land disposal by the LDR; (2) an Inventory Report, identifying all areas at RFP where mixed wastes are stored and including the same information requested for the Storage Report; (3) a Land Disposal Restrictions Determination Report, providing DOE's determinations as to whether or not the radioactive mixed wastes, not identified in the Storage Report, are prohibited wastes covered by the FFCA; (4) a Waste Characterization Report, characterizing all waste stored at RFP and all waste streams generated at RFP; (5) Treatment Report No.1, identifying treatment and disposal technologies and capacities currently available at DOE or commercial sites, alternate technologies under development, and giving the bases and assumptions for the preceding; (6) Treatment Plan No.1, for each prohibited waste identified in Treatment Report No.1, establishing milestones and schedules for development and implementation of treatment technologies that will satisfy LDR requirements; (7) Treatment Report No.2, covering the same information required for Treatment Report No.1 for those radioactive mixed

wastes covered by the FFCA but not identified in the Storage Report; (8) Treatment Plan No.2, for each prohibited waste identified in Treatment Report No.2, providing the same information for these wastes as provided in Treatment Plan No.1; (9) a Waste Minimization Report, identifying methods for minimizing the generation of wastes, including process changes, segregation, and substitution of less toxic materials; (10) a National Report of Prohibited Waste and Treatment Options, prepared by DOE Headquarters, giving the information for all DOE sites called for in reports (1) through (8), as well as an assessment of whether a national treatment priority scheme is necessary and, if so, the elements of the proposed scheme; and (11) a One Year Report, describing how DOE has achieved compliance with LDR, or if not achieved, a description of all alternatives and how each alternative has been "fully explored and exhausted." Revisions to the Storage Report and Inventory Report, and an amendment to the Waste Minimization Report are also required by the FFCA.

Most of the reports required by the FFCA do not have definite delivery dates, but rather dates based on lead regulatory agency (currently the EPA) approval. For the four reports being prepared by the Process Technology Development (PTD) group in the Plutonium Operations directorate, for example, Treatment Report No.1 is due 30 days after EPA approval of the Storage Report submitted by Waste Operations. Treatment Plan No.1 is due 90 days after submittal of Treatment Report No.1. In like manner, Treatment Report No.2 and Treatment Plan No.2 will have due dates based on the EPA submittal date of the Land Disposal Restrictions Determination Report.

The Storage Report was submitted to the EPA on October 19, 1989. This report, Treatment Report No.1, prepared by PTD, discusses those wastes identified in the Storage Report as mixed LLW and mixed TRU wastes. The report describes how the wastes were generated and in what quantity, possible technologies (DOE and commercial) for treatment and disposal of the wastes, the facilities and capacities now available and projected for the future, and identifies bases and assumptions used in generating the report. The report relies on the information relative to waste characterization given in the

Wastren report (4).

Treatment Report No.1 only presents options to be considered, not a solution for each waste problem. In many cases, the wastes must be characterized before solutions can be addressed. Some wastes may not be land disposal restricted once characterization is complete. A sampling and analysis program is of primary importance in this effort. Depending on the amount of waste to be treated, sufficient data may need to be collected to enable basing the treatment technology design on two times the standard deviation to encompass the worst case, that is, a specific batch of waste not meeting typical criteria for that waste.

However, it is also true that some waste categories are no longer being generated and very little of that waste is stored in the backlog. Spending a great deal of time and money characterizing that waste would not be a good allotment of resources. Serious consideration will be given to whether it makes sense to simply develop a treatment that meets the regulatory standards without completely characterizing the waste first.

A considerable effort has been made by PTD personnel to obtain information from the literature and to incorporate that information in the report. Literature searches were conducted at the EPA offices in Denver, Colorado; the Colorado School of Mines; the University of Colorado; and the RFP library. However, additional references are being found and the search is continuing.

Also, some of the information requested on DOE facilities and capacities is not yet available; the National Report on Prohibited Waste and Treatment Options, to be prepared by DOE Headquarters, is not due to be submitted to the EPA until January 17, 1990. For this reason, information on DOE technologies and capacities, and the amount of capacity, if any, over that required to treat given wastes at that DOE site, is not complete in this report. Additional information will be obtained by site visits and additional engineering evaluations of process technologies.

Outside resources were also used in preparing the report. An External Review Board (see Appendix) was convened to review the report with emphasis on waste treatments (Section 5.0) and wastes to be treated (Section 6.0). A consultant from BDM Corporation supplied information on the waste treatment capabilities at other DOE facilities (Section 7.0). In addition, personnel from LANL provided input.

2.3 References

(1) International Technology Corporation, "Radioactive Mixed Waste Treatment Alternatives Study", Project No. 301001 89 14 05, pp 1-2 and 1-3, June 1989.

(2) Federal Register, 54, No. 224, November 22, 1989.

(3) "Federal Facilities Compliance Agreement and Compliance Order on Consent," Docket No. :RCRA (3008) VIII-89-25, September 19, 1989.

(4) Wastren, Inc., "Rocky Flats Plant Low-Level Mixed Waste Plan" November 29, 1989.

3.0 SCOPE

As noted in Section 2.0, this report discusses potential treatments for each of the 18 prohibited wastes identified in the Storage Report as currently being LDR. Treatments are listed for a prohibited waste, if, in theory, they could be used to treat the waste to yield a waste form that meets land disposal requirements and the applicable disposal facility's Waste Acceptance Criteria (WAC), as well as the governing Department of Transportation (DOT) regulations. No attempt is made in this report to rank or preferentially order the identified technologies for a given waste. Such a ranking scheme is required for Treatment Plan No.1. This section briefly discusses, however, the ranking criteria to be used in the preparation of that ranking scheme for Treatment Plan No.1.

Two waste treatment technology ranking schemes have been prepared in draft form: (1) a short term evaluation method, and (2) a long term evaluation method. The short term treatment evaluation scheme was developed with the goal of treating a prohibited waste to meet the land disposal requirements as soon as possible. Assuming that the current prohibited wastes in storage at RFP are in violation of the RCRA regulations, this short term ranking scheme attempts to highlight technologies that will rectify the alleged out-of-compliance situation as quickly as possible. Four criteria are used: (1) effectiveness, (2) availability, (3) secondary waste stream, and (4) efficiency.

Once the short term criteria are applied and treatment alternatives are selected that will be effective in meeting the RCRA regulations and can be implemented in production quickly, the long term ranking criteria will be applied. The goal of the long term ranking criteria is to select technologies for development that reduce volume and toxicity of the final waste form and do so in an efficient manner. Criteria to be used in the ranking are: (1) environmental impacts, including volume reduction and degree of effectiveness (i.e., proven effectiveness, percent of LDR concentration limits achievable, and longevity); (2) reliability and maintainability; (3) stage of development

of the technology; (4) capital and operating costs, including maintenance; and (5) physical characteristics of the waste form.

The ranking schemes will be discussed in greater detail in Treatment Plan No.1.

Individual mixed waste streams considered in this report are identified and briefly described as follows. Except where noted, wastes are LLW.

Name	Description
1. Solidified Bypass Sludge	Aqueous precipitation sludge generated from treatment of plutonium recovery process wastes; stabilized with diatomaceous earth/Portland cement absorbent
2. Soil and Cleanup Debris	Soil/debris picked up during cleanup activities from areas with RCRA constituents and radioactivity
3. Cutoff Sludge	Sludge accumulated beneath equipment in a decontamination facility
4. Solidified Organics/TRU	Organics mixed with gypsum cement
5. Combustibles and Filters/TRU	Mixed TRU combustibles (paper, cloth, plastics, etc.) and filters
6. Metal/TRU	Metal size reduced for drum or box storage contaminated with RCRA constituents and radioactivity
7. Aqueous Sludge/TRU	Aqueous precipitation sludge generated from treatment of plutonium recovery process wastes
8. Miscellaneous Waste/TRU	Raschig rings (borosilicate glass) and blacktop, concrete, dirt, and sand from construction/demolition activities.
9. Particulate-Sludge Waste/TRU	Spent ion exchange resin used in plutonium recovery operations
10. Roaster Oxide	Depleted uranium chips that have been roasted to an oxide form
11. FBI Oil	Contaminated oil originally destined for the fluidized bed incinerator (FBI)

12. Combustibles	Combustibles (paper, cloth, plastics, etc.) contaminated with listed solvents
13. Metal	Cuttings and chips from machining non-fissile metals, contaminated with listed constituents
14. Filters	Primarily high efficiency particulate air (HEPA) and activated carbon filters
15. Cemented Composite Chips	Chips of composite metals (including depleted uranium) from machining operations, contaminated with listed solvents and solidified with cement
16. Acid	Waste acid solution from electrochemical process tanks
17. PCB Solids	Contaminated equipment and cleanup materials (primarily rags) generated during removal of PCB-containing equipment
18. PCB Liquid	Organic liquid waste containing PCB's and low level radioactivity as well as capacitors.

Approximately 50 technologies were considered for each of the above wastes. Treatments are listed as an alternative for a prohibited waste if, in theory at least, they could be used to treat the waste to yield a waste form that meets RCRA/HSWA and all other relevant criteria.

The interaction between waste minimization and waste treatment is crucial and demands that well-integrated plans and schedules be adopted. While waste minimization in general will not impact wastes already generated, it is expected that future generation rates will change dramatically, as will waste forms in some cases. The present report is consistent with minimization data available at present, but the major integration will be addressed in the Treatment Plans.

Current and planned treatment capabilities within the DOE complex were analyzed for their suitability to treat the wastes in this report. Capacity determinations and detailed engineering evaluations of each potential capabil-

ity will be made for Treatment Plan No.1. No commercial sector treatment capabilities were identified.

4.0 WASTE ACCEPTANCE CRITERIA

In anticipation of disposal facilities becoming available that can take low-level mixed and TRU mixed waste, criteria can be developed, with limited assumptions, that will provide a model for mixed wastes currently being stored or generated. Comparison to the assumed waste forms requirement for each waste will make treatment needs evident. This section discusses LLW, TRU and mixed waste acceptance criteria (WAC). For LDR purposes, it is not too important whether the waste is LLW or TRU; the important thing is whether the waste can be treated to either convert the mixed waste to straight LLW or TRU, or to meet LDR for mixed wastes.

4.1 Low Level Waste Acceptance Criteria

With respect to low-level waste disposal criteria, all of DOE's low-level waste disposal facilities operate under their own WAC. But since the governing regulations are the same, the various WACs are similar. RFP's low-level waste has traditionally gone to the NTS, so NTS WAC are the bases for treatment of low-level mixed waste to remove the hazardous components. These treatments give low-level waste, or low-level mixed waste that will meet LDR requirements, e.g., will pass the Toxic Characteristic Leaching Procedure (TCLP) and Extractive Procedure (EP) tests.

Defense waste accepted at NTS must be radioactive and meet the general waste form criteria. The following general LLW form criteria were taken from NVO-325, UC-70B, "Nevada Test Site Defense Waste Acceptance, Certification, and Transfer Requirements," dated October 1988.

"These waste form criteria are based on current DOE LLW management practices and guidelines. DOE/NV recognizes that these requirements may need to be modified for certain waste streams. However, any modifications must be tailored to the specific waste stream and intended disposal environment, i.e., shallow land disposal (SLD) or greater confinement disposal (GCD), and must

not compromise the performance objectives for the disposal site or violate any permit requirements.

General Waste Form Criteria

A. Transuranics. LLW must have a transuranic nuclide concentration not greater than 100 nCi/g.

B. Hazardous Material. LLW offered for disposal at NTS waste management sites shall not exhibit any characteristics of, or be listed as, hazardous waste as identified in Title 40 CFR 261, "Identification and Listing of Hazardous Waste."

C. Free Liquids. LLW disposed at NTS waste management sites must not contain free liquids. Waste containing liquids shall be solidified or have an absorbent, stabilizer, or both, added and mixed so that there will not be any free liquid during packaging, handling, transport, and disposal. Ion exchange resins must be dewatered and solidified to be considered as a solid waste. Liquid waste solidified by the urea-formaldehyde process will not be accepted. Minor liquid residue remaining in well-drained containers, or liquids which have been entrapped, are acceptable. In no cases shall free liquid content exceed 0.5 percent by volume.

D. Particulates. Fine particulate wastes shall be immobilized so that the waste package contains no more than one weight percent of less-than-ten-micrometer-diameter particles, or 15 weight percent of less-than-200-micrometer-diameter particles, with radioactive contamination. When immobilization is impractical, the waste packaging shall include a sealed liner and be overpacked.

E. Gases. Radioactive gases shall be stabilized or absorbed so that pressure in the waste packaged does not exceed 1.5 atmospheres at 20°C. Compressed gases as defined by Title 49 CFR 173.300, including unpunctured aerosol cans, will not be accepted for disposal.

F. Stabilization. Where practical, waste shall be treated to reduce volume and provide a more physically and chemically stable waste form. If necessary the waste shall be treated to assure that significant quantities of harmful gases, vapors, or liquids are not generated. Wastes

shall not react significantly with the packaging during normal storage, shipping, and handling time.

G. Etiologic Agents. LLW containing pathogens, infectious wastes, or other etiologic agents as defined in Title 49 CFR 173.386 will not be accepted for disposal at NTS.

H. Chelating Agents. LLW containing chelating or complexing agents at concentrations greater than one percent by weight will not be accepted.

I. GCD Waste. LLW waste that meets the following waste form guidelines must be identified for placement in GCD at the Area 5 RWMS LLW Management Unit.

1. Wastes defined by DOE Order 5820.2A, Chapter III, as not being suitable for SLD. For example, LLW designated as greater-than-class C as defined in Title 10 CFR 61.55, "Waste Classification."
2. Volatile or mobile radionuclides when properly packaged to be acceptable for shipping, e.g., high-specific-activity tritium.
3. Radioactive material that would exist in a concentration greater than 0.1 millicurie per gram when decayed for 100 years. For example:
   a. cesium-137 at concentrations greater than 1 millicurie per gram.
   b. strontium-90 at concentrations greater than 1 millicurie per gram.
   c. cobalt-60 at concentrations greater than 50 curies per gram.
   d. radium-226 at concentrations greater than 0.1 millicurie per gram.
4. Other waste forms, on a case-by-case basis, that do not meet NTS requirements for SLD.

J. Bulk LLW. Bulk LLW shall be solid and meet the requirements of Title 49 CFR 173.425(c)(1). Bulk waste is accepted for disposal only at the Area 3 RWMS Bulk Waste Management Unit.

Additional Criteria For Mixed Waste

Waste offered for SLD at the Area 5 RWMS Mixed Waste Management Unit (MWMU) must be hazardous as defined in Title 40 CFR 261, "Identification and Listing of Hazardous Waste," or state regulations, and be radioactive (intermixed with radioactive material). Mixed waste will not be accepted for GCD or for bulk disposal.

Except for the restriction against chemically hazardous materials, mixed waste (MW) must meet all the waste form criteria listed previously for LLW. In addition, MW must meet the following criteria.

A. Treated Waste. Mixed waste must receive any required treatment prior to shipping the waste to the Area 5 RWMS. Mixed waste can only be treated according to EPA-approved methods.

B. Restricted Waste. Mixed waste prohibited from land disposal under Title 40 CFR 268, "Land Disposal Restrictions," will not be accepted unless treated as specified under Title 40 CFR 268, Subpart D, "Treatment Standards."

C. Reactive Waste. Reactive or ignitable waste that has not been treated, rendered, or mixed in accordance with Title 40 CFR 264.312, "Special Requirements for Ignitable or Reactive Waste," will be reviewed for acceptance. Explosives, pyrophoric materials, or high-heat generators are not acceptable for MW disposal. Cyanide and sulfide-bearing wastes in concentrations greater than ten percent by weight as CN^- or S^{-2} will not be accepted. (If accepted for disposal, potentially incompatible waste must be identified by the most appropriate compatibility group listed in Title 40 CFR 264, Appendix V, "Examples of Potentially Incompatible Waste.")

D. Liquids. Mixed waste must not have free liquids as demonstrated by EPA Test Method 9095, "Paint Filter Liquids Test," specified in Title 40 CFR 264.314(c).

E. Polychlorinated Biphenyls (PCBs). PCB-contaminated waste will not be accepted for disposal at NTS unless the PCB concentration meets munici-

pal solid waste disposal levels. See Title 40 CFR 761.60 for PCB disposal requirements."

4.2 Transuranic Waste Acceptance Criteria

The planned disposal site for TRU waste is WIPP and WAC have been established for WIPP. Therefore, TRU mixed waste will require treatment to remove hazardous components to give a TRU waste or TRU mixed waste meeting LDR requirements and the WIPP WAC.

The WAC for TRU waste disposed at the WIPP are contained in WIPP-DOE-069, Revision 2, "TRU Waste Acceptance Criteria for the Waste Isolation Pilot Plant, September 1985." The following criteria for contact-handled waste were taken from this report. All TRU waste in this treatment report are contact-handled.

Contact-Handled Waste Acceptance Criteria

A. Gas Generation. Waste packages containing waste forms known or suspected of gas generation such that a combination of overpressure and explosive mixtures might damage the container in the long term, shall be provided with an appropriate method for pressure relief.
Each TRU waste shipper shall provide the following data for each waste package:

1. Total activity (alpha Ci)
2. Waste form description (from Certification Plan)
3. Mass and volume percent of organic content

For purposes of transportation and emplacement (short term) there will be no mixtures of gases or vapors in any package which could, through any credible spontaneous increase of heat or pressure, or through an explosion, significantly reduce the effectiveness of the packaging.

B. Immobilization. Powders, ashes and similar particulate waste materials shall be immobilized if more than 1 weight percent of the waste matrix

in each package is in the form of particles below 10 microns in diameter, or if more than 15 weight percent is in the form of particles below 200 microns in diameter.

C. Liquid Wastes. Transuranic waste shall not be in free-liquid form. Minor liquid residues remaining in well drained bottles, cans, and other containers are acceptable.

D. Explosives and Compressed Gases. TRU waste shall contain no explosives or compressed gases as defined by 49 CFR 173, Subparts C and G.

E. Pyrophoric Materials. Pyrophoric materials, other than radionuclides, shall be rendered safe by mixing with chemically stable materials (e.g., concrete, glass, etc.) or processed to remove their hazardous properties. No more than 1 percent by weight of the waste in each package may be pyrophoric forms of radionuclides, and these shall be generally dispersed in the waste.

F. Radioactive Mixed Waste. Transuranic waste shall contain no hazardous wastes unless they exist as co-contaminants with transuranics. Waste packages containing reactive materials shall be identified with the appropriate Department of Transportation (DOT) label. Transuranic-contaminated corrosive materials shall be neutralized, rendered noncorrosive, or packaged in a manner to ensure container adequacy through the design lifetime. Hazardous materials to be reported are listed in 40 CFR 261, Subparts C and D.

G. Waste Containers. Waste containers for emplacement at the WIPP shall be noncombustible and meet all the applicable requirements of 49 CFR 173.412 for Type A packaging. In addition, they shall have a design life of at least 20 years from date of certification, including labeling. Any waste containers that appear to be bulged or otherwise damaged shall be repacked or overpacked in a container meeting the above requirements.

H. Waste Package Handling. Contact-handled TRU waste packages shall be provided with cleats, offsets, chimes, or skids, for handling by means or fork trucks, cranes, or similar handling devices. Lifting rings and other auxiliary lifting devices on the packages, if provided, shall be recessed, offset, or hinged, in a manner which does not inhibit stacking

the packages.

I. Waste Package Weight. Contact-handled TRU waste packages or package assemblies shall weigh no more than 25,000 pounds (11,360 kg).

J. Waste Package Size. Contact-handled TRU waste packages or package assemblies shall not exceed 12 x 8 x 8.5 feet (3.7 x 2.4 x 2.6 m) in overall L x W x H dimensions.

K. Surface Dose Rate. Waste packages shall have a maximum surface dose rate at any point no greater than 200 mRem/hr. Neutron contributions of greater than 20 mRem/hr to the total package dose rate shall be reported separately in the data package.

L. Surface Contamination. Contact-handled TRU waste packages or package assemblies shall have a removable surface contamination no greater than 50 pCi/100 cm^2 for alpha-emitting isotopes and 450 pCi/100 cm^2 for beta-gamma-emitting isotopes.

M. Thermal Power. Individual contact-handled TRU Waste packages in which the average thermal power density exceeds 0.1 watt/ft^3 (3.5 W/m^3) shall have the thermal power recorded in the data package.

N. Nuclear Criticality. The fissile or fissionable isotope content for contact-handled TRU waste containers shall be no greater than the following values, in Pu-239 fissile gram equivalents:

200 g per 55-gallon (0.21 m^3) drum
100 g per 30-gallon (0.11 m^3) drum
500 g per DOT 6M container
5 g per ft^3 (0.028 m^3) in boxes, up to 350 g maximum

For materials other than Pu-239, U-235, and U-233 which shall be treated as equivalent, fissile equivalents shall be obtained using ANSI/ANS-8.15-1911 (1).

O. Pu-239 Equivalent Activity. Waste packages shall not exceed 1000 pCi of Pu-239 equivalent activity.

P. Other. Specific labeling and data package requirements are also specified, but are not of significance for this report.

4.3 Hazardous Waste Acceptance Criteria

For hazardous wastes, the EPA has established a very complex regulation that sets criteria and standards that must be met before a waste can be accepted for land disposal. The intent of the regulation is to implement EPA's goal to significantly reduce the hazards associated with wastes going to land disposal facilities. The regulation, titled Land Disposal Restrictions and found in 40 CFR 268, establishes concentration standards that must be met or treatment technologies that must be used. Some uncertainty in the applicable criteria in the LDR exists because (1) only two-thirds of the EPA hazardous waste designations have been addressed by the LDR, the remaining one-third are scheduled to be restricted from land disposal by May 8, 1990 and (2) the LDR specifically exempt mixed waste from most of the standards until May 8, 1990. (There is an EPA proposal in the November 22, 1989, Federal Register to grant a two-year national capacity variance for mixed wastes.) Where standards have been established, but only for straight hazardous wastes, it is assumed that the same numbers would be used for mixed waste. Where standards have not yet been established, some assumptions are made.

Wastes identified in this report are estimated to be land disposal restricted based on either sampling results or process knowledge. The applicable regulations effective now for these wastes are those finalized for spent solvents (F001-F005) and the California List wastes. Other standards for wastes herein have not been finalized to date, namely the criteria for establishing a characteristic hazardous waste, and constituent concentrations in the waste extract (CCWE) from the toxic characteristic leach procedure (TCLP) testing. Proposed regulations for mixed waste were published in the November 22, 1989, Federal Register; however, they are quite extensive and could not be reviewed for incorporation in this report (2).

The wastes herein possess one or more of the following EPA hazardous waste numbers.

Hazardous Waste Number	Description
F001	Spent halogenated solvents used in degreasing
F002	Spent halogenated solvents
F003	Spent non-halogenated solvents
F004	Spent non-halogenated solvents
F005	Spent non-halogenated solvents
F006	Wastewater treatment sludges from electroplating operations
F007	Spent cyanide plating bath solutions from electroplating
F008	Plating bath residues from electroplating
F009	Spent stripping and cleaning bath solutions from electroplating where cyanides are used.
D001	Characteristic of ignitability
D002	Characteristic of corrosivity
D003	Characteristic of reactivity
D004	EP toxic for arsenic
D005	EP toxic for barium
D006	EP toxic for cadmium
D007	EP toxic for chromium
D008	EP toxic for lead
D009	EP toxic for mercury
D010	EP toxic for selenium
D011	EP toxic for silver

The PCB waste in this report has the distinction of being regulated under the AEA, RCRA and its amendments, and the Toxic Substances Control Act

(TSCA). The applicable RCRA regulations are summarized below.

The land disposal restrictions for spent solvents (F001 - F005) and the California List wastes are effective now and are summarized as follows. The table shows the allowable concentration of a given constituent in the TCLP extract.

Component F001-F005 Solvents	CCWE Concn, ppm*
1,1,1 Trichloroethane	0.41
1,1,2 Trichloro - 1,2,2 Trifluoroethane	0.96
Acetone	0.59
Methylene chloride	0.96
2-Butanone (methyl ethyl ketone)	0.75
Ethylbenzene	0.053
Carbon tetrachloride	0.96
Trichloroethylene	0.091
Tetrachloroethene	0.05
Tetrachloroethane	0.05
Toluene	0.33
Xylene	0.15

* The values in the table apply to non-wastewaters.

If a nonliquid hazardous waste exceeds 1000 ppm in halogenated organic compounds, it is restricted from disposal because of California List restrictions. The California List restrictions also ban the disposal of liquid hazardous wastes that exceed 50 ppm PCBs.

Land disposal restrictions for radioactive mixed waste will go into effect on May 8, 1990. The proposed regulations in the November 22, 1989, Federal Register are complex and lengthy, and could not be adequately reviewed for this report. Their possible impact will be considered for Treatment Plan No.1 to determine possible impact on treatments being considered. Assuming that the regulations currently in effect for hazardous wastes will remain un-

changed for mixed wastes gives the following limits. The table shows the assumed allowable concentration in the waste or the waste extract from the TCLP test.

Component F006, F007, F008 & F009	Assumed Allowable Concn, ppm
CCWE	
Cadmium	0.066
Chromium (total)	5.2
Lead	0.51
Mercury	0.025
Nickel	0.32
Silver	0.072
CCW	
Cyanides (total)	590
Cyanides (amenable)	30

The concentration limits for characteristic waste and for F006 through F009 wastes are not yet established. It was assumed that these will remain as stated in 40 CFR 268 for regular hazardous waste for the characteristics of ignitability, reactivity, and corrosivity. For EP toxicity, it was assumed that if the above assumed TCLP limits for the CCWE for F006 through F009 wastes were met, then EP toxicity requirements would be satisfied as well.

4.4 References

(1) ANSI/ANS-8.15-1981. American National Standard for Nuclear Criticality Control of Special Actinide Elements.

(2) Federal Register, 54, No. 224, November 22, 1989.

5.0 WASTE TREATMENT PROCESS DESCRIPTIONS

Numerous waste treatments were identified which may be useful for mixed wastes at Rocky Flats. These treatments were grouped into five main categories: thermal processes, chemical processes, physical processes, immobilization, and high level waste solidification techniques. The maturity of each treatment was also evaluated and categorized as either commercially available, developmental, or laboratory scale.

It should be noted that there are no permitted mixed waste treatment facilities. The categorization noted above as to commercial, developmental, or laboratory scale relates to the stage of development of the treatment process only. Detailed schedules for implementing the selected treatment process will be contained in Treatment Plan No. 1. This will include the anticipated time to obtain a permit.

Information on treatment processes is given in this section to provide a basis for process comparisons when specific wastes are discussed in subsequent sections.

5.1 Thermal Processes

5.1.1 Process Descriptions

Thermal processes are generally destructive technologies when used for wastes containing organic compounds. Some thermal processes have been developed for managing wastes containing inorganic constituents; these processes generally entrain the constituents in a residue which is easier to manage and considered much less hazardous. Because of the potential for generating off-gases containing particulates, acids, volatile heavy metals, and other undesirable constituents, it is expected that an off-gas system will be required for most of the thermal processes that follow. Components of an off-gas system usually include an afterburner, a scrubber, a filter bank,

baghouse, electrostatic precipitator, cyclone, or a combination of these. The processes described are rotary kiln incinerator, infrared incinerator, advanced electric reactor, molten salt, glass melter, microwave melter, controlled air incineration, wet air oxidation, cyclone incineration, Belgium Incineration Process, liquid injection incineration, plasma arc furnace, fluidized bed incineration, in situ vitrification, metal melting, oxygen enhanced incineration, and roasting.

5.1.1.1 Rotary Kiln Incinerator

Rotary kilns are used to destroy organic wastes by oxidation. Wastes and auxiliary fuel enter the elevated end of an inclined, refractory-lined, cylindrical kiln. The wastes are oxidized to gases and ash while passing through the kiln. Operating temperatures typically range between 650-980°C. Residence time may range from several seconds for gases to several hours for solid wastes. Exhaust gases are treated in an afterburner operating at temperatures between 760-1,315°C (1). Rotary kilns can handle a wide variety of wastes including solids up to four inches in diameter.

A similar process known as the fast rotary kiln has better reported efficiency than the normal rotary kiln due to an increased rotational speed (up to 20 rpm). This increased rotational speed allows for better heat transfer and combustion (2). Rotary kiln technology is commercially available.

5.1.1.2 Infrared Incinerator

Infrared incinerators oxidize organic wastes by using infrared heating elements. Wastes are conveyed through a furnace on a woven metal conveyor belt; liquid wastes are passed through the furnace using pans placed on the conveyor belt. Oxidation of wastes to gases and ash occurs as the wastes pass under the infrared heating elements. Operating temperatures within the

primary chamber range between 260-1,000°C, with a residence time, for solids, of 10-180 minutes. Off-gases pass through a secondary combustion chamber to complete the combustion of remaining organic constituents. Operating temperatures within the secondary chamber range between 540-1,260°C with a residence of 2-5 seconds. This system has the capacity for very precise control of temperature and residence time. Infrared incineration technology is commercially available.

5.1.1.3 Advanced Electric Reactor

An advanced electric reactor converts organic wastes to non-hazardous compounds by thermolysis. Destruction of the wastes takes place in an electrically-heated, annular, porous-carbon-core reactor. The wastes are added at the top of the reactor and are broken down by thermolysis at approximately 2,200°C while passing through the reactor. An unusual feature of the process is that thermal energy is transferred to the wastes by means of radiation rather than conduction or convection. Off-gases pass through a secondary combustion chamber to ensure complete combustion of organic substances. This process is limited to liquid wastes atomized to droplets no larger than 1,500-microns and solid wastes no larger than 35 mesh. Sludges cannot be handled by this process. This unit is also known as a high temperature fluid wall reactor (1). Advanced electric reactor technology is commercially available.

5.1.1.4 Molten Salts

In this process, wastes are incinerated in molten sodium carbonate. The heat from the process destroys organic constituents while the salt traps inorganic contaminants and acts as a scrubber for off-gases and particulates. The salt must be continually changed because of the buildup of contaminants. Other salts may also be formed during the neutralization of acidic off-gases. Wastes treated by this process must have a low ash and low water content (2).

Molten salt development process was curtailed in 1988.

5.1.1.5 Glass Melter

Glass melters are used for processing wastes by trapping inorganic and metallic constituents in a glass matrix while destroying the organic constituents. Organic liquids, dry sludges, and combustibles are first mixed with glass formers and then introduced into the cavity of a glass melter. Electrodes protruding into the cavity below the level of the molten waste pass an electrical current through the waste/glass mixture (joule heated). Resistance to the current generates the heat within the waste/glass mixture. Operating temperatures generally range between 950-1,250°C, and are controlled by adjusting the voltage across the electrodes. Glass melters can also be gas-fired or electrically-heated but the joule heated melters are a good compromise between energy efficiency and controlled off-gassing.

Excess oxygen is introduced into the chamber and residence time is controlled to ensure complete destruction of all organic contaminants. Off-gas treatment is required, and sludges formed during the off-gas treatment can be recycled through the melter. The molten glass with the trapped ash is drawn from the bottom of the melter into heated drums. The drums are slowly cooled to approximately 700°C and then forced-air cooled to prevent crystallization. The drums are sealed, leak tested, and prepared for off-site shipment. This process reduces volume (approximately 10-30%) and creates a disposable waste form (2,3,4). Glass melters are commercially available.

5.1.1.6 Microwave Melter

Microwave melters are similar to glass melters except the heating is done using microwave energy and the melting takes place in the shipping container. Microwave melters may reduce the volume (up to 80%) of certain types of wastes, while at the same time forming a solidified, glass-like mass.

Dry wastes and glass frit are introduced into the drum, which is attached to a microwave generator. The drum becomes the resonant cavity and temperatures between 700-1,300°C are generated. Organic substances, air, and moisture are driven off, and metallic and inorganic substances are trapped in the glass matrix. When the glass is removed from the chamber, the waste is in a form that is appropriate for shipment and disposal. Microwave melting is a developmental process (5).

5.1.1.7 Controlled Air Incineration

Controlled air incineration is a variation of conventional incineration practices. Wastes enter the primary combustion chamber and are heated to approximately 870°C in an oxygen-poor atmosphere. (If the wastes are heated in a oxygen free atmosphere, this process is called pyrolytic decomposition.) The wastes are broken down into gases and ash. By minimizing the air flow rate, turbulence in the chamber is restricted, and ash dispersion reduced. Off-gases then enter a secondary combustion chamber and are oxidized in an oxygen rich atmosphere. Exhaust gases pass through a scrubber and HEPA filter system before being released. Wastes which have a tendency to form refractory tars and cokes when burned in an oxygen-poor atmosphere are not suited to this type of incineration. This process is also referred to as the Los Alamos Process (6). Controlled air incineration technology is commercially available.

5.1.1.8 Wet Air Oxidation

Wet air oxidation is the aqueous phase reaction of suspended organic substances and oxygen at elevated temperatures (175-340°C) and pressures (300-3000 psi). These conditions convert carbon to carbon dioxide, hydrogen to water, nitrogen to ammonia and nitrogen gas, phosphorus to phosphoric acid, sulfur to sulfuric acid, and halogens to the corresponding halogenic acids. The process is well suited for waste streams that are too dilute to incinerate

economically. Typically, aqueous waste streams containing 1-3% organic constituents by volume can be treated with this process (2).

Catalyzed wet oxidation is very similar to the wet air oxidation process, except that a catalyst is added. The process uses nitrate and bromide ions in an acidic solution to catalyze decomposition of the organic constituents. Other catalysts, such as copper ion, have been used to improve the performance of conventional wet air oxidation processes. Aqueous waste streams containing up to 5% organic constituents by volume are treated using this process (2).

Supercritical water oxidation is also similar to wet air oxidation, except that supercritical water at 375°C and 3210 psi is used as the reacting medium. The process is capable of treating waste streams that contain up to 20 vol % organic constituents (1). Wet air oxidation technology is commercially available.

5.1.1.9 Cyclone Incinerator

The cyclone incinerator is a cylindrically-shaped combustion chamber into which a mixture of fuel, waste, and air are introduced tangentially to produce a flow having a tangential velocity that varies inversely with radial position. The resulting high shear provides intense mixing and complete combustion. Temperatures range from 870 to 1,650°C with ash being removed from the exhaust gases by centrifugal force. This method is useful primarily for liquid organic wastes, and additional fuel is required to maintain operating temperatures (2). Cyclone incinerators are commercially available.

5.1.1.10 Belgium Incineration Process

The Belgium Incineration Process (BIP) is a high temperature combustion process designed to form a basaltic glass product from a precise combination of five different feed material categories which include: 1) synthetic material (PVC, etc.), 2) natural materials (wood, paper, etc.), 3) inorganic materials, 4) glass, and 5) metals. The unique feature of this process is that it could require little additional non-waste mineral material which would make the overall efficiency of the process very high.

The proper combination of material is fed into a furnace and fired in excess air at 1500-1600°C. The molten combustion residues are poured into a monolithic block or dropped into cooling water to form irregularly-shaped small granules. The 3.3 kg/l discharge product has a leach resistance and mechanical strength similar to borosilicate glass. This developmental process has been tested in a 150 kg/hr facility with a wide variety of simulated and real waste compositions which include transuranic and beta-gamma emitting isotopes from both the combustible and incombustible waste feed material (7).

5.1.1.11 Liquid Injection Incineration

Liquid injection incinerators consist of a refractory-lined combustion chamber and a series of atomizing devices, usually fluid (i.e., air or steam) atomized nozzles. These devices introduce waste material into the combustion chamber in finely divided droplets vigorously mixed with air. Following combustion, the flue gases are cooled and treated with air pollution control devices to remove particulates and to absorb acid gases. Complete combustion requires adequate atomization of the waste in order to provide for efficient mixing with the oxygen source. Pretreatment may be required for wastes that are difficult to atomize, vary in heat content, or are not pumpable (1). These incinerators are well developed and commercially available.

5.1.1.12 Plasma Arc Furnace

The Plasma Arc Furnace (PAF) uses a high temperature plasma gas to process waste material. In the PAF, waste material introduced into the reactor is melted to a slag by the intense heat of a plasma initiated by an electric arc between the torch and the reactor vessel. The rotation of the reactor vessel forces the slag to the outer walls and away from the center discharge hole in the bottom of the reactor. By adjusting the rotational speed of the reactor, the residence time of material in the reactor can be controlled. Volatile gases released from the waste material are subjected to the high temperatures of the plasma gas as they pass through the bottom discharge hole. At plasma temperatures, organic molecules completely decompose to individual atoms. The high temperature off-gas is quenched while oxygen is introduced to promote the formation of water and carbon dioxide.

The off-gas is treated through conventional flue gas treatment systems to remove acid gases, particulate, and volatile metals prior to release to the atmosphere. The slag formed in the reactor is discharged and allowed to freeze in waste disposal containers. The glassy slag binds hazardous materials such as toxic metals and radioactive isotopes, rendering them leach resistant. In addition, the PAF is reported to be a technology capable of processing a wide variety of materials such as liquids, solids, slags, combustibles, and inerts. The plasma arc is still in the demonstration stage of development (8).

5.1.1.13 Fluidized Bed Incineration

Fluidized bed incinerators are vessels containing a bed of graded, inert granular material, usually silica sand or a catalyst. The heated bed material is expanded by combustion air forced upward through the bed. As waste material is mixed with the hot fluidized bed material, heat is rapidly transferred to the waste feed. When the waste dries and burns, heat is transferred back to the bed. Excess air requirements are reduced because of the high degree of turbulence in the bed which ensures thorough mixing between

combustion gases and the waste feed. Inorganic materials in the waste stream are entrapped in the bed which necessitates continuous removal and make-up of bed material.

Secondary combustion chambers (including the freeboard volume above the bed) are always used to give additional time for complete combustion. Off-gas treatment following the secondary reaction chamber is dependent on the waste feed and may include a wet scrubber, baghouse, or electrostatic precipitator.

A variation in fluidized bed technology has been applied to waste disposal and is referred to as circulating bed combustion. Unlike a conventional fluidized bed which has a fixed bed depth, high velocity air introduced at the bottom of the combustion chamber transports the bed out of the fluidization zone. Subsequently, the eluted solids are captured and partially returned to the fluidization zone. This results in entrainment of wastes and subsequent combustion along the entire height of the combustion section. Complete destruction is reported to be attained at relatively low temperatures because of this high degree of turbulence. Secondary combustion chambers are said not to be required because of the high degree of destruction. Off-gases pass through a cyclone, which captures and recycles solids to the combustion zone. The combustion gases pass through a heat recovery system and baghouse filter or other air pollution device prior to discharge to a stack.

The application of conventional fluidized bed and circulating bed systems to treat hazardous wastes is based on extensive commercial operating experience for coal, refinery sludge, paper mill sludge, and sewage sludge combustion (1).

5.1.1.14 In Situ Vitrification

This process is potentially useful for in situ treatment of soils contaminated with radioactive materials and heavy metals. Electrodes are placed in the contaminated soils and high potentials are used to drive current

through the soil. Resistive losses in the soil produces heat which vitrifies the glass-making components in the soil. After cooling, the partially vitrified soil immobilizes the waste materials. Off-gases formed during heating are collected and treated with appropriate systems (9). The process is in the developmental stage. Specific application depends on site conditions and the wastes involved.

5.1.1.15 Metal Melter

Contaminated metals are placed in a refractory crucible and melted. The volatile organics are either destroyed or volatilized during heating while hazardous metal components are trapped in the metal matrix. Off-gases generated during melting process may require treatment. This treatment technique is not suited for waste metals contaminated with significant quantities of volatile heavy metals. Metal melting technology is commercially available (10).

5.1.1.16 Oxygen Enhanced Incineration

Oxygen enhanced incineration replaces the air used in conventional incinerators with oxygen or an air-oxygen mixture. This incineration technique reduces gas flow rates and related particulate carryover, reduces the volume of flue gas requiring treatment, and can increase operating temperatures and removal efficiencies. A major disadvantage is the careful control of oxygen required for safe operation. This process has been commercially demonstrated by the EPA using a rotary kiln incinerator (11).

5.1.1.17 Roasting

Roasting is the oxidation of metals to give metal oxides. This process is usually conducted at temperatures ranging from 500-950°C. Pyrophoric waste metals such as uranium are often roasted to reduce potential fire hazards. Roasting equipment is commercially available (12).

5.1.2 References

1. USEPA, Mobile Treatment Technologies for Superfund Wastes, EPA/540/2-86/003 (f), U. S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, Washington, D.C., September 1986.

2. H. Freeman, Innovative Thermal Hazardous Organic Waste Treatment Processes, U. S. Environmental Protection Agency, Noyes Publication, Park Ridge, NJ, 1985.

3. L. R. Crisler, A Preliminary Assessment of Nine Waste Form Products/Processes for Immobilizing Transuranic Wastes, RFP-3131, Rockwell International, Rocky Flats Plant, Golden, CO, September 1980.

4. Preliminary Evaluation of Alternative Waste Form Solidification Processes, PNL-3244, Pacific Northwest Laboratory, Richland, WA, April 1980.

5. R. D. Petersen, A. J. Johnson, and S. D. Swanson, Application of Microwave Energy for In-Drum Solidification of Simulated Precipitation Sludge, RFP 4148 Rockwell International, Rocky Flats Plant, Golden, CO, August 1987.

6. LATA, Assessment of Alternatives to Routine Operation of the Fluidized Bed Incinerator (Draft), Los Alamos Technical Associates, Inc. Los Alamos, NM January 1988.

7. N. Van De Voorde, et al., An Integrated System for the Conditioning of Radioactive Solid Wastes & Liquid Waste Concentrates, in "Fuel Reprocessing and Waste Management Proceedings, American Nuclear Society International Topical Meeting, Jackson, WY, August 1984.

8. R. C. Eschenbach, R. A. Hill, and J. W. Sears, Process Description and Initial Test Results with the Plasma Centrifugal Reactor, presented at the Forum on Innovative Hazardous Waste Treatment Technologies, Atlanta, GA, 1989.

9. J. B. Berkowitz, et al., "Unit Operations for Treatment of Hazardous Industrial Wastes," Noyes Data Corporation, Park Ridge, NJ, 1978.

10. H. E. Boyer and T. L. Gall, "Metals Handbook Desk Edition," American Society for Metals, Metals Park OH, 1985.

11. P. S. Daley, Cleaning Up Sites with On-Site Process Plants, Environ. Sci. Technol., 23, 912 (1989).

12. T. Rosenquist, "Principles of Extractive Metallurgy," McGraw-Hill Book Company, New York, NY, 1974.

5.2 Chemical Processes

5.2.1 Process Descriptions

A chemical process alters the chemical structure of contaminants within wastes. Chemical processes are generally intended for liquid wastes with either organic or inorganic contaminants. The contaminants may be made less soluble, converted to nonhazardous compounds, or converted to a less hazardous form. The processes described are aqueous phase alkaline destruction, catalytic dehalogenation, ultraviolet light/oxidation, electrochemical removal of metals, acid digestion, biodegradation, neutralization, precipitation, chemical reduction-oxidation, and acid leaching.

5.2.1.1 Aqueous Phase Alkaline Destruction

The aqueous phase alkaline destruction process converts organic materials into oil. The organic material is digested in the absence of oxygen using a mild alkali at temperatures of 250-400°C and pressures of 500-3,000 psi. Residence time can range from 0.5 to 5 hours. Product oil can have a heating value up to 90% of diesel oil. Organic material or sludges can be halogenated liquids or granulated solid material. This process has been tested using Lindane and chloroform with almost total destruction achieved with no dioxin by-products produced (1).

This developmental process has been extensively tested by Battelle and the American Fuel and Power Corp. using a pilot-plant unit. A feed of primary, undigested, municipal sewage sludge was converted to a usable fuel oil, char, and wastewater. The pilot plant operates at a rate of 30 l/hr,

using a feed material containing 20% solid material and 5% anhydrous sodium carbonate. Metals in the feed material are concentrated in the char, while organic solvents remain in the fuel oil.

5.2.1.2 Catalytic Dehalogenation (Hydrodechlorination)

Catalytic dehalogenation is a developmental process for decontaminating wastes containing halogenated organic solvent. The process replaces halogen atoms on the halogenated compounds with hydrogen atoms with the use of an appropriate catalyst. If chlorine is replaced, the process is called hydrodechlorination. The potassium polyethylene glycolate (KPEG) process is similar to hydrodechlorination but specifically developed to handle polychlorinated biphenyls (PCBs) waste streams (2).

5.2.1.3 Ultraviolet Light/Oxidation

The ultraviolet light/ oxidation process uses ultraviolet (UV) light in the presence of a strong oxidizing agent, hydrogen peroxide and/or ozone to decontaminate aqueous waste streams containing hazardous organic compounds. The oxidant is added to the wastewater which is then irradiated with UV light. The UV light converts the ozone and/or hydrogen peroxide into highly reactive hydroxyl radicals. Decontamination of the waste occurs when the organic contaminants react with the hydroxyl radicals to form nonhazardous compounds (3). Feed waste streams are usually limited to clear gases and liquids with organic contents of less than 0.1%. Ultraviolet light/oxidation technology is commercially available.

5.2.1.4 Electrochemical Removal of Metal Contaminants

Three electrochemical processes are potential candidates for extracting waste metal ions from solution: electrodialysis, electrowinning, and electrodecontamination.

The electrodialysis process has been used by the electroplating industry to effectively concentrate metals in process waste streams (4). An aqueous waste stream, containing metal salts, is fed into the center chamber of a three-chamber unit. Semi-permeable membranes are used to separate the center chamber from the other chambers. The feed wastes are then subjected to an electrical charge. The anions, mainly sulfates and chlorides, pass through an anion-permeable membrane and collect in the anode chamber. The cations, mainly metals, pass through a cation-permeable membrane and concentrate in the cathode chamber. The deionized water remains in the center chamber and is ready for discharge or further treatment. The concentrated anionic and cationic solutions require further processing. Electrodialysis has been used for treating waste streams containing nickel, copper, cyanide, chromic acid, iron, and zinc. The process works best for pretreated, acidic wastes containing one concentrated metal (5).

Electrowinning is a process for creating a high purity metal. An acidic solution containing metal ions is electrolyzed, depositing or plating the metal on the cathode, while additional acid is formed at the anode (6). The process operates at ambient or elevated temperatures. Both electrodialysis and electrowinning are commercially available technologies.

Electrodecontamination is essentially an electropolishing or electrolytic dissolution process. The contaminated surface is dissolved anodically in a concentrated acid or alkaline solution. Any radioactive contamination that is either on the surface or entrapped within scratches and other surface imperfections is removed and released into the electrolyte by the surface dissolution process. This process can reduce radioactivity on metal surfaces to background levels (7). Equipment for electrodecontamination is commer-

cially available.

5.2.1.5 Acid Digestion

In the acid digestion process, combustible waste is added to sulfuric acid heated to 230 to 300°C. The initial step in acid digestion is carbonization of the organic material. Some of the carbon is converted to carbon dioxide by sulfuric acid, but most oxidation of carbon is done by the action of an added oxidant. Nitric acid is commonly used as the oxidant, although hydrogen peroxide has also been used successfully. Sulfur dioxide is a by-product of acid digestion, and either oxidant will convert this material to sulfuric acid which can be reused.

Most solid and liquid organic materials carbonize readily, although lower boiling materials tend to volatilize to varying degrees. Others, particularly halogenated materials, tend to react more slowly. In all cases off-gas scrubbing is necessary, and sulfuric acid can be regenerated and reused (8,9,10,11). Acid digestion is a developmental process.

5.2.1.6 Biodegradation

Biological treatment uses microorganisms to degrade hazardous organic compounds to nonhazardous constituents. A number of biological degradation processes destroy organic pollutants in industrial and municipal wastewater. For example, industry extensively uses activated sludge treatment because it is cost effective and it destroys most organics in aqueous waste streams. It is a suspension of aerobic and facultative microorganisms which oxidize soluble organics in the presence of dissolved oxygen. Sedimentation is used to separate the biological sludge from the treated wastewater.

Fixed-film reactors, rotating biological contractors, aerated lagoons, and trickling filters all perform the same type of biodegradation as takes

place with activated sludge. Although each of these commercially available systems has its own way of contacting the waste with the biological agent, they share many of the same drawbacks. Breakdown of most hazardous components is generally slow (12). Volatilization of the hazardous component can take place, thus requiring containment and adequate air pollution control. The biological agent often cannot tolerate fluctuations in waste stream. Heavy metals often concentrate in the sludge, posing problems for land disposal (13).

Constructed wetlands (14), composting, and land farming use organic substrates to remove metals and break down hydrocarbons from liquids or semisolid material. In general, these systems work by chemically- and biologically-mediated sulfate reduction.

In situ biodegradation destroys hazardous organic constituents without removing the soil for treatment. These processes uses anaerobic microorganisms pumped into or through the hazardous waste. The process is most applicable to a hazardous waste spill at a site with favorable hydrological conditions for in situ treatment.

5.2.1.7 Neutralization

Neutralization is the addition of a base to an acid to convert the acid to a salt. Waste salt solutions in general are easier to treat than either the acid or the base.

Neutralization does not require any special equipment, and the chemistry would be well known in most cases (15). Depending upon their composition, the salts or other by-products of the neutralization process would require additional treatment.

5.2.1.8 Precipitation

Precipitation is a technique most suitable for removing soluble metal species. Precipitation occurs when other species are added which, in combination with a dissolved metal species already in solution, forms an insoluble material. This insoluble material separates as a solid phase which can be separated from the liquid phase by filtration or other physical methods (16). Commercial equipment is available to support precipitation operations.

5.2.1.9 Chemical Reduction-Oxidation

Reduction-oxidation (often called redox) reactions involve the chemical transformation of reactants in which the oxidation state of one reactant is raised while the other is lowered. The process destroys or reduces the toxicity of many toxic organics and heavy metals. Common oxidizing agents include ozone, hypochlorite, chlorine, and hydrogen peroxide. Many of these agents are used to treat cyanides. Common reducing agents include sodium borohydride, sulfur dioxide, ferrous sulfate, and sodium sulfate. A common example of a chemical reduction treatment of hazardous waste is the use of ferrous sulfate to reduce the highly toxic and mobile Cr(VI) to Cr(III) (11). Equipment for most redox reactions is commercially available.

Electrochemical oxidation has also shown potential as a method for destroying toxic chemicals such as PCBs, pesticides, and other hazardous materials. In this process, a slurry or solution of the waste material is fed into an electrochemical cell containing nitric acid and silver in the form of Ag(I). The silver, which serves as a catalyst, is electrolytically converted to Ag(II), a strong oxidizing agent which is normally not stable. The Ag(II) oxidizes hazardous components and is converted to Ag(I) which is regenerated to repeat the cycle. Pilot scale work is planned, pending the outcome of ongoing laboratory scale experimental work (17).

5.2.1.10 Acid Leaching

Acid leaching is a process in which acid solutions are used to preferentially dissolve contaminants from the surface of solid materials. This process can be used to remove metallic hazardous elements and to reduce levels of radioactive contaminants on solid materials. The acid wastes generated in the process require further treatment. Equipment for acid leaching processes is commercially available (18).

5.2.2 References

1. H. Freeman, Innovative Thermal Hazardous Organic Waste Treatment Processes, U. S. Environmental Protection Agency, Noyes Publication, Park Ridge, NJ, 1985.

2. USEPA, Land Disposal, Remedial Action, Incineration and Treatment of Hazardous Waste, Proceedings of the Fourteenth Annual Research Symposium, EPA/600/9-88/-021, U. S. Environmental Protection Agency, Office of Research and Development, Risk Reduction Engineering Laboratory, July 1988.

3. D. G. Hager and C. E. Smith, The UV-Hydrogen Peroxide Process: An Emerging Technology for Groundwater Treatment, presented at "HazMat West 85," Long Beach, CA, December 3-5, 1985.

4. K. F. Cherry, "Plating Waste Treatment," Ann Arbor Science Publishers, Inc., Ann Arbor, MI, 1982.

5. USEPA, Treatability Manual: Volume III. Technologies for Control/Removal of Pollutants, EPA-600/2-82/001c, Section III.3.1.7, U. S. Environmental Protection Agency, Office of Research and Development, Washington, D.C., September 1981.

6. R. D. Pehlke, "Unit Processes of Extractive Metallurgy," American Elsevier Publishing Company, Inc., New York, NY, 1973.

7. R. P. Allen, H. W. Arrowsmith, L. A. Charlot, and J. L. Hooper, Electropolishing as a Decontamination Process: Progress and Applications, PNL-SA-68-58, Pacific Northwest Laboratories, Richland, WA, April 1978.

8. C. R. Cooley and R. E. Lerch, Chemical Digestion of Low Level Nuclear Solid Waste, U. S. Patent 3,957,676, May 18, 1976.

9. C. R. Allen, R. G. Cowan, M. D. Crippen, and G. L. Richardson, Radioactive Acid Digestion Test Unit - Final Status Report, HEDL-TME 82-23, Hanford Engineering Development Laboratory, Richland, WA, September 1982.

10. J. A. Partridge and G. P. Bosuego, Acid Digestion of Organic Liquids, HEDL-TME 80-74 UC-70, Hanford Engineering Development Laboratory, Richland, WA, October 1980.

11. R. E. Lerch, Application of Acid Digestion to Reprocessing Wastes and Chemicals, HEDL-TC-362, Hanford Engineering Development Laboratory, Richland, WA, September 1975.

12. USEPA, Mobile Treatment Technologies for Superfund Wastes, EPA/540/2-86/003 (f), U. S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, Washington, D.C., September 1986.

13. B. L. Blaney, Alternative Techniques for Managing Solvent Wastes, in "Treatment Technologies for Hazardous Wastes," H. M. Englund and L. F. Mafrica, Eds., APCA Reprint Series, RS-13, Int. J. Air Pollut. Contl. Haz. Waste Mgt., Pittsburgh, PA, 1987.

14. R. R. Cohen, private communication, December 12, 1989.

15. B. H. Mahan, "University Chemistry," Addison-Wesley Publishing Company, Reading, MA, 1969.

16. J. S. Fritz and G. H. Schenk, "Quantitative Analytical Chemistry," Allyn and Bacon, Boston, MA, 1966.

17. D. O'Sullivan, Electrolytic Oxidation Destroys Toxic Wastes, Chem. Eng. News, June 12, 1989.

18. C. B. Gill, "Nonferrous Extractive Metallurgy," John Wiley & Sons, New York, NY, 1980.

5.3 Physical Processes

5.3.1 Process Descriptions

A physical process is one that changes the form of the waste by removing specific contaminants without either chemical or thermal destruction of the contaminants or by reducing the volume of the waste. Frequently, decontamination is accomplished by transferring the hazardous constituents from one medium to another. Further, once the contaminant substances are transferred to the second medium, it may be possible to collect or destroy the contaminants. Physical treatment is often directed toward aqueous waste streams contaminated with hazardous organic compounds. The processes described are aqueous wash, volatilization, filtration, crystallization, supercriti-

cal fluid extraction, ion exchange, reverse osmosis, solvent extraction, distillation, air stripping, activated carbon adsorption, steam stripping, comminution/beneficiation, and centrifugation.

5.3.1.1 Aqueous Wash

Washing with an aqueous solution is a physical separation method used to dissolve soluble materials from a host material. Filtration or other physical separation techniques may be required to separate the aqueous wash solution. This is not a destructive technique, but would be useful if components of a mixture are more amenable to treatment separately rather than mixed together.

Washing has been used primarily to remove soluble contaminants from soils (1), but the technique has also been applied to remove actinides from plastics and other materials not soluble in aqueous media (2). This technique does not require complicated equipment, and appropriate equipment is commercially available.

5.3.1.2 Volatilization

Volatilization (also known as low temperature thermal stripping) is a physical process for removing volatile and semivolatile compounds from solids. In this process, contaminated solid materials are heated to temperatures below typical organic decomposition temperatures (less than 550°C). At these temperatures the organics vaporize and can either be directly incinerated or collected for further treatment (3). Commercial equipment such as rotary driers and thin film evaporators are commonly used in evaporation processes. Vacuum equipment is also sometimes incorporated in these processes to increase volatilization rates and reduce temperature requirements.

5.3.1.3 Filtration

Filtration is a physical separation method used to remove suspended solids from a fluid by passage of the fluid through a filter medium. It is also useful for dewatering sludges and soils using vacuum, high pressure, or gravity (1). This is not a destructive technique, but would be useful if components of a mixture are more amenable to treatment separately rather than mixed.

Filtration is widely used throughout industry for a variety of applications, and different filtration methods are commercially available. Fluids can be separated from solids by allowing vacuum or gravity to draw the fluid through the filter medium, or by using pressure to force the fluid through the filter medium.

5.3.1.4 Crystallization

Crystallization (often called freeze crystallization) is the use of ultra-low temperature refrigerants, such as liquid nitrogen, to separate mixed materials. For example, in a mixture of components with different freezing points, the temperature of the mixture can be lowered until the first component freezes. The frozen component is rinsed to remove contamination and remelted as pure material. The crystallization process has been evaluated for application to wastewater treatment, solvent recovery, metal solution recovery, and incinerator enhancement. The equipment used for these processes is commercially available, but the processes will require additional development beyond the pilot plant stage (1).

5.3.1.5 Supercritical Fluid Extraction

Supercritical fluid extraction is a process in which the critical or compressed fluid form of an environmentally safe gas is used as a solvent to extract organic hazardous constituents from waste. Carbon dioxide, in the critical state, and propane, in the compressed liquid state, are two examples

of gases used. This process has been used to remove hazardous organic compounds from soils, recover oil from sludge, and to recover solvents from slurries. Additional processing steps are required if destruction of the solvents and waste oils is required (4). Supercritical extraction technology is commercially available.

5.3.1.6 Ion Exchange

Ion exchange is a reversible process for extracting ions, primarily metal ions, from aqueous wastes. During this process, there is an exchange of ions between the contaminated liquid phase and the solid resin which produces no permanent change to the structure of the resin. When saturated with waste ions, the resins are either disposed or regenerated with appropriate solutions. Although this process is usually used to extract metal ions, cyanide complexed with metallic ions such as iron can also be removed (5). Ion exchange is commercially available technology and has been used to remove metal ions from water (1).

5.3.1.7 Reverse Osmosis

A reverse osmosis (also called hyperfiltration) unit uses a semipermeable membrane for extracting uncontaminated water from a volume of water containing dissolved solids. Hydrostatic pressure, sufficient to overcome the osmotic pressure of the solutes, is applied to a contaminated solution. Uncontaminated water is forced through the membrane, while the dissolved solids are concentrated in the remaining, smaller volume of water. For efficient operation, the applied pressure generally exceeds the osmotic pressure by at least 150 psi. The upper limit for applied pressure is approximately 800 psi.

The reverse osmosis process may be used for removing both organic and inorganic dissolved solids. Pilot scale investigations have demonstrated that

greater than 90 percent removal is possible for several organic species including chloroform, 1,1-dichloroethane, 1,2-dichloroethane, 1,1,1-trichloroethane, and trichloroethylene (6). Reverse osmosis technology is commercially available. Other membrane technologies which use semipermeable membranes to separate contaminants from liquids include microfiltration, ultrafiltration, bipolar separation, and pervaporation.

5.3.1.8 Solvent Extraction

In solvent extraction, contaminants in one solvent are removed by mixing with a second immiscible solvent or immobilized phase. The process is applicable to solvents containing both metallic and organic contaminants, although metallic contaminants often require complexing prior to extraction. The solvents treated with this process are generally contaminated aqueous solutions.

Solvent extraction may be performed in a mixer-settler, centrifugal contactor, or packed tower. The solvent passes countercurrent to the aqueous stream. After the exchange, the contaminated solvent is sent to a regeneration unit for reclamation. During the exchange, some of the solvent could remain in the aqueous solution, which would require additional treatment before solution disposal. The organic phase can be immobilized as in extraction chromatography. Solvent extraction technology is commercially available (7).

5.3.1.9 Distillation

Distillation uses evaporation and condensation to separate the more and less volatile components in a feed stream. If the materials to be separated both have significant vapor pressures at the required processing temperature, fractional distillation is usually required. Fractional distillation takes place in a column containing packing material or a series of trays. Heat is

added to the column which partially vaporizes the feed stream. When the vapors contact the packing material or trays, the less volatile components tend to condense and drip back to the bottom of the column. The more volatile components remain in the vapor phase and work their way to the top of the column where they are collected in an accumulator. The less volatile distillation by-products eventually collect in the bottom of the column and are removed. Fractional distillation may be useful for reclaiming spent solvents from machining operations or for purifying aqueous waste streams highly contaminated with organics (1).

5.3.1.10 Air Stripping

Air stripping is the mass transfer of volatile organics from a liquid to a gas phase. The transfer continues until an equilibrium is established between the two phases. The mass transfer rate is limited by the amount of liquid surface area exposed to the air because diffusion occurs only at the air-liquid interface. Within a column, contaminated liquid flows, from top-to-bottom, over packing material creating a large surface area. At the same time, air passes from bottom-to-top over the liquid. The volatile hydrocarbons enter the passing air which is then treated and emitted. Extraction efficiencies exceeding 99% are possible. A liquid phase carbon adsorption unit is commonly used as a polishing unit, following an air stripper, to increase the efficiency of contaminant removal (8). Properly sized solid materials can also be treated with similar type processes. Air stripping equipment is commercially available.

5.3.1.11 Activated Carbon Adsorption

Activated carbon is an effective method for removing volatile organic compounds from aqueous wastes. It works by adsorbing organic molecules onto the surface of the carbon particles. Carbon particles have a high surface area to weight ratio (in the range of 500-1,500 m^2/g) which creates a large

surface area for interaction with the organic molecules. At the interior of the carbon, the attractive forces are balanced; however, at the surface the forces are unbalanced. This imbalance results in a net inward attraction which causes migration of the organic molecules into the carbon (9). The effectiveness of organic adsorption is over 99%. Activated carbon adsorption technology is commercially available.

5.3.1.12 Steam Stripping

Steam stripping is a commercially available process for removing organic compounds from aqueous solutions. This process is related to both air stripping and to fractional distillation.

Heated waste streams are fed into a tower filled with packing material or trays. As the waste flows downward through the tower, steam passes countercurrent to the stream. Organic contaminants that have volatilized are carried away in the steam. Steam stripping has also been used successfully by industry to remove hydrogen sulfide and ammonia. Further, steam stripping should be effective for the removal of many chlorinated hydrocarbons, including 1,1,2-trichloroethane, carbon tetrachloride, and 1,2-dichloropropane. This method may be used to treat solutions with organic concentrations ranging from 100 ppm up to 20 percent (10). Properly sized solid materials can also be treated with similar type processes.

5.3.1.13 Comminution and Beneficiation

Comminution refers to size reduction of materials by any of several processes including grinding, cutting, shredding, chopping, crushing, etc. Beneficiation refers to any of several processes in which a process stream is improved. Examples of such processes include screening, washing, sorting, tabling, and magnetic separation.

Combinations of various comminution and beneficiation processes are often required as a pretreatment to alter the size and composition of a waste stream. Since these methods are pretreatments, they are not further discussed in this report as are the primary treatment technologies designed to effect separations permitting land disposal. Numerous comminution and beneficiation processes are commercially available.

5.3.1.14 Centrifugation

Centrifugation is a separation technique based on the application of centrifugal force to a mixture or suspension of materials to separate the materials based on their densities. The materials to be separated are placed in a centrifuge and rotated at high speeds to impart a force up to 17,000 times that of gravity. As a result of these forces, the higher density materials are forced to the outer wall while the lower density materials are concentrated at the middle of the centrifuge. This commercial separation technique may be useful for separating emulsified mixtures of oil and water and for concentrating sludges.

5.3.2 References

1. USEPA, Mobile Treatment Technologies for Superfund Wastes, EPA/540/2-86/003 (f), U. S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, Washington, D.C., September 1986.

2. J. D. Wilkins and S. J. Wisbey, Preliminary Studies on the Washing of Plutonium-Contaminated Materials for Plutonium Recovery, PCMWP/P170, Chemistry Division, Harwell Laboratory, Oxfordshire, England, 1976.

3. P. S. Daley, Cleaning Up Sites with On-Site Process Plants, Environ. Sci. Tech., 23, 912, 1989.

4. USEPA, Project Summary: Near Critical CO_2 Extraction of Hazardous Organics from Acrylonitrile, Pesticide, and Steel Mill Wastes, EPA/600/S2-87/005, U. S. Environmental Protection Agency, Hazardous Waste Engineering Research Laboratory, Cincinnati, OH, May 1987.

5. W. Fries, Cyanide Treatment: Detoxification by Complexation, U. S. Patent 3,788,983.

6. S. D. Faust and O. M. Aly, "Chemistry of Water Treatment," Butterworth Publishers, Woburn, MA, 1983.

7. G. W. Dawson and B. W. Mercer, "Hazardous Waste Management," John Wiley & Sons, New York, NY, 1986.

8. USEPA, Aeration to Remove Organic Compounds from Ground Water, EPA/600/2-86/024, U. S. Environmental Protection Agency, interim report to the Office of Drinking Water, Cincinnati, OH, March 1984.

9. J. W. Hassler, "Purification with Activated Carbon: Industrial, Commercial, Environmental," Chemical Publishing Co., Inc., New York, NY, 1974.

10. J. B. Berkowitz, et al., "Unit Operations for Treatment of Hazardous Industrial Wastes," Noyes Data Corporation, Park Ridge, NJ, 1978.

5.4 Immobilization

5.4.1 Process Descriptions

Immobilization processes convert wastes to a form that is more easily managed, and/or is acceptable for disposal. Current waste disposal criteria dictate that wastes intended for disposal at a mixed waste facility contain limited free liquids and particulates. This form of treatment is directed toward solid and liquid wastes, soils, and ash.

Stabilization and solidification are processes that change the physical structure of wastes for encapsulation of the waste component. Stabilization alters the solubility or chemical reactivity of the waste. Solidification converts the waste to a solid. The immobilization processes described are bitumen solidification, sorption, lime-fly ash pozzolan cementation, Portland cement, polymer encapsulation, and organic solidification.

5.4.1.1 Bitumen Solidification

Bitumen solidification uses a high molecular weight hydrocarbon like bitumen or asphalt to encapsulate waste. Bitumen or asphalt occurs naturally or is obtained as a by-product of petroleum or coal-tar refining.

In the solidification process, the wastes and liquefied bitumen are fed into an extruder heated to approximately 215°C. The extruder mixes the waste and bitumen while evaporating the water. The mixture of waste and bitumen is poured into steel drums and the evaporated water is collected for additional treatment. The resultant waste form encapsulates the waste and has good leach resistance. Bitumen solidification is a commercially available process used in France, West Germany, Belgium, and Japan (1). However, flammability and off-gasing from the bitumen are major concerns involved with this solidification technique, and for this reason it is not considered further in this report.

5.4.1.2 Sorption

Sorbent material is added to wastes to produce a waste form that is easier to handle. Sorbent may react chemically or physically with the waste stream. Commonly used materials include bottom ash, fly ash, and kiln dust from lime and cement manufacture, and diatomite. The pH level may need adjusting depending on the type of sorbent used. Both the quantity of product needed to ensure that no free liquids are generated, and the compatibility between product and the waste and/or contaminants need to be considered when choosing a sorbent (2). Several different types of sorbents are commercially available.

5.4.1.3 Lime-Fly Ash Pozzolan

Fly ash, or other pozzolanic material, is mixed with the wastes along with lime. The final mixture is placed into forms and allowed to harden. Oil and grease, and compounds such as sodium borate, calcium sulfate, and potassium dichromate, may adversely affect the strength of the solidified mass by interfering with bonding (3).

5.4.1.4 Portland Cement

In this widely used solidification process, Portland cement, water and a solid waste form are mixed together and cast into various containers to harden. Some cement solidification processes mix the constituents directly in the final waste drum. The strength and leach resistance of the final waste form varies widely depending on the final composition and numerous processing variables. Fly ash, clay, blast furnace slag, diatomite or other commercial products are sometimes added to the batched cement to alter the properties of the final waste form. Addition of Portland cement is a relatively inexpensive process but significantly increases the weight and volume of the final waste form (4).

5.4.1.5 Polymer Encapsulation

In polymer encapsulation, dried waste is either extruded with a thermoplastic or mixed with a thermo-setting plastic to form a solid waste form. Polymer encapsulation is more tolerant of chemical changes in the waste stream than cementation processes and is more efficient. However, flammability of the organics remains a concern. Commercially available equipment and materials are used (5).

5.4.1.6 Organic Solidification

Several commercial products are available to solidify oil/solvent wastes. The primary purpose of the solidification agent is to eliminate free liquids in the shipping container. The inorganic materials used in these materials are often either calcium sulfate-based gypsum cement or a mixture of treated silicates. Polynorbornene is a polymeric material available for solidifying oil/solvent wastes.

The solidification materials work differently in solidifying the oil/solvents and result in structurally different monoliths. The gypsum cement encapsulates the emulsified oil and forms a monolithic structure with a compression strength of 400 to 500 psi. The silicates act as an absorbent/thickening agent and form a soft monolithic mixture with a consistency of a very thick grease or paste. The polymer absorbent absorbs the oil/solvent and forms a friable monolithic structure. The solidified monoliths formed with the treated silicates and polymer have little compression strength compared to the gypsum-solidified waste.

Some organic solidification processes solidify the waste directly in the final waste drum. Organic solidifying agents are an easy, low capital method for treating organic wastes, but these methods are inefficient and only physically absorb or encapsulate the waste oils (2).

5.4.2 References

1. L. R. Crisler, A Preliminary Assessment of Nine Waste Form Products/Processes for Immobilizing Transuranic Wastes, RFP 3131, Rockwell International, Rocky Flats Plant, Golden, Colorado, September 1980.

2. USEPA, Handbook for Stabilization/Solidification of Hazardous Wastes, EPA/540/2-86/001, U.S. Environmental Protection Agency, Hazardous Waste Engineering Research Laboratory, Cincinnati, OH, June 1986.

3. Preliminary Evaluation of Alternative Waste Form Solidification Processes, PNL-3244, Pacific Northwest Laboratory, Richland, WA, April 1980.

4. R. M. Neilson and P. Colombo, Solidification of Simulated Transuranic Contaminated Incinerator Ash Wastes Using Portland Type I Cement, BNL 50854, Brookhaven National Laboratory, Long Island, NY, 1978.

5. P. D. Kalb and P. Colombo, Polyethylene Solidification of Low-Level Wastes, BNL 51867, Brookhaven National Laboratory, Long Island, NY, 1984.

5.5 High Level Waste Solidification Techniques

Reactor and other types of wastes generated in the DOE complexes contain a variety of fission products with short half-lives which are not only intensely radioactive but can also remain thermally hot for several years. Wastes of this nature require special solidification techniques to ensure that they are fully immobilized for the required length of time. Several high level waste (HLW) solidification processes are briefly discussed, including the glass ceramic process, glass pellets in inorganic binder, supercalcine hot-isostatic pressing process, synroc hot isostatic pressing process, titanate process, cermet process, and fuetap concrete process.

Fortunately, Rocky Flats does not have high level wastes to treat. It is remotely possible that some of these techniques might be applicable, or that selected small-volume wastes might be sent to such a facility for processing, and for these reasons HLW solidification methods are mentioned. They are not considered further in this report.

5.5.1 Process Description

5.5.1.1 Glass-Ceramic Process

As in the normal glass melting process described in Section 5.1.1.5, the developmental glass ceramic-process vitrifies the waste in a joule-heated glass melter but the composition of the glass is adjusted slightly to have more alumina and less boron oxide. This compositional change allows a glass-ceramic to be formed. A glass-ceramic is a material of fine-grained crystals relatively uniform in size, randomly oriented, and homogeneously dispersed in a glass matrix. These materials have superior leach resistance and better

thermal and mechanical shock resistance than borosilicate glass (1). To form the glass-ceramic, glass from the joule melter is placed in drums and cooled in a controlled-temperature cycle to first nucleate a fine dispersion of crystals in the glass, and then to maximize the final crystalline content of the glass product. The nucleation of the crystals requires four hours at approximately 650°C while the crystal growth step takes six hours at approximately 850°C. After cooling, the drum is sealed, leak tested, and packed for storage.

5.5.1.2 Glass Pellets in Inorganic Binder

In this process, wastes are first incorporated in a glass matrix by melting in a joule-heated glass melter. The molten glass is subsequently poured into a marble-making device or pelletized. The glass marbles or pellets are placed into a metal drum and further encapsulated in a cement or metal matrix. After casting the metal or cement, the drum is sealed, welded, and checked. It is then inspected, decontaminated, and placed in storage. The total waste loading for this waste form is 4 wt % (2). This process has been tested on a laboratory scale at several facilities.

5.5.1.3 Supercalcine Hot-Isostatic Pressing Process

Supercalcine is a silicate-based material produced by calcining the oxides of silicon and the nitrates of calcium, aluminum, and strontium. These components are combined in carefully defined proportions, so that during calcination they will react with the components of radioactive waste to form stable apatite, fluorite, scheelite, pollucite, and spinel crystal structures (2).

In this process, a liquid or slurry waste material is mixed with selected liquid additives to form a supercalcine solution which is subsequently dried to a fine powder in a spray calciner. The powder is vibratory-packed

into drums and heated to denitrate and sinter the supercalcine powder into a semi-dense monolith with a porosity of about 20%. The drum is then filled with crushed glass and is placed into a hot isostatic press (HIP). The HIP is degassed by vacuum and is gradually heated to melt the glass. When the glass has melted, the HIP is pressurized with argon to pressures as high as 15,000 psi and heated to temperatures as high as 1150°C. Under high temperature and pressure, the glass acts as a hydraulic fluid which evenly compacts the supercalcine. This finalizes the formation of the desired mineral phases and compacts the supercalcine to near its theoretical density of 4.9 kg/l. The drum is then sealed, leak tested, and packed for storage. This process is in the laboratory stage of development.

5.5.1.4 Synroc Hot-Isostatic Pressing Process

Synroc is an acronym for a series of synthetic, igneous rock systems consisting of a combination of thermodynamically compatible minerals. The selected minerals are known to have the capacity to accept and to retain radioactive waste elements in their crystal lattices.

In the Synroc Hot-Isostatic Pressing (SHIP) process, the slurried waste material is converted to a dry powder in a spray calciner. The dry powder is blended with crushed Synroc additives that are sized for maximum packing density. The blended materials are then added to a canister, vibrated, sintered, and hot isostatically pressed as in the supercalcine hot-isostatic pressing process. The SHIP process product density is 4.4 kg/l. This process is in the laboratory stage of development (1).

5.5.1.5 Titanate Process

This process produces a titanate-ceramic waste product. The liquid and slurry feed material, calcium hydroxide, and granular titanate additives are mixed together in large heated tanks. In the heated tanks, water is boiled away, and nitrates are removed with continued heating. A charge of the resulting material is added to a die in a uniaxial hot press, in which a dense monolith is produced. The uniaxial hot press can reach temperatures and pressures up to 1100°C and 1000 psi. The die containing the pressed monolith is removed from the press and cooled. Later the titanate monolith is removed from the die and is placed in a drum. The titanate monolith is expected to have an oxide waste loading of 25 wt % and a density of 4 kg/l (2). This process is in the laboratory stage of development.

5.5.1.6 Cermet Process

Cermet is a composite material containing fine ceramic particles dispersed in a leach-resistant, metallic phase. Waste species such as iron and nickel that can be reduced to the metallic state by carbon monoxide or hydrogen are incorporated into the metallic phase as an alloy (2). The dispersed ceramic phase can be tailored using chemical additions chosen to confine nonreducible waste, radioactive actinide nuclides, and other heavy metals. The cermet process requires feed material of soluble species or slurries.

The process involves the dissolving and mixing of feed material and cermet forming additives in molten urea at 150°C. The process solution is then dried to a fine powder in a spray calciner and mixed with a binder, such as water or wax, in a pin-mixer agglomerator to yield small, dense pellets which have an oxide waste loading of 30 wt %. The pellets are then extruded at pressures as high as 4500 psi into cylinders. The cylinders are reduced/-sintered in a kiln at temperatures as high as 1200°C. In the kiln, the combination of heat and a hydrogen atmosphere causes the reduction of iron and nickel oxides to a metallic state. The resulting monolith is inserted in a canister, sealed, leak tested, and packed for storage. Off-gases from the

reduction/sintering kiln are processed through a scrubber system. The density of the waste product can be as high as 6.5 kg/l. The cermet process is currently in the laboratory stage of development.

5.5.1.7 Fuetap Concrete Process

The Fuetap Concrete Process is an elevated temperature and pressure concrete process. The feed material could be liquids, powdered solids, or slurries. In a batch process, the feed material is combined with water, cement, fly ash, and illitic clay in a mixer. The mixed batch is poured into a drum and placed in an autoclave for a period of 1.5 to 7 hours. The autoclave can have temperatures up to 110°C and pressures up to 600 psi. The combined high temperature and pressure in the autoclave prevents boiling and accelerates the hardening of the concrete (2). The drum is maintained at the elevated pressure and temperature for 24 hours to permit the concrete to set, and then cooled for another 24 hours. The drum is removed from the autoclave and placed in air storage for an extended period of time (years) to allow free water in the concrete to evaporate. After all free liquids are removed the drum is sealed, leak tested, and packed for storage. The waste oxide loading is approximately 19 wt % with a final form density of 1.7 kg/l. A pilot scale unit has been operated.

5.5.2 References

1. L. R. Crisler, A Preliminary Assessment of Nine Waste Form Products/Processes for Immobilizing Transuranic Wastes, RFP 3131, Rockwell International, Rocky Flats Plant, Golden, CO, September 1980.

2. Preliminary Evaluation of Alternative Waste Form Solidification Processes, PNL-3244, Pacific Northwest Laboratory, Richland, WA, April 1980.

6.0 INDIVIDUAL WASTE STREAMS

Eighteen land disposal prohibited waste forms have been identified at Rocky Flats that require treatment. This section discusses each of these wastes - how they are (or were) generated, their characteristics, possible treatment alternatives, and a qualitative evaluation of the treatment alternatives.

When a treatment process has been selected for each of the wastes (the selection will be discussed in Treatment Plan No. 1) the capacity of the required equipment will be determined by the size of the current inventory of the waste as well as the anticipated rate of future waste generation.

If the treatment process is selected for more than one waste (multiple use) the total capacity required for processing the inventory and generation of each waste will be considered in determining equipment size.

6.1 Solidified Bypass Sludge

6.1.1 Generation Processes

The bypass sludge is a portion of the solid waste generated in the Liquid Waste Treatment Facility in Building 374. This sludge results when waste waters containing small amounts of plutonium, americium, and uranium are transferred to the Building 374 hydroxide precipitation process and treated with reagents to promote flocculation and precipitation of the radioactive materials. The agglomerated waste is concentrated in a clarifier. Decanted clarifier overflow is sent to an evaporator while the settled sludge is partially dewatered by passing through a rotary drum vacuum filter coated with diatomaceous earth. The sludge is continuously cut from the drum filter and placed into a waste drum. A mixture of diatomite and Portland cement is used as an absorbent and is continually added to the waste drum along with the sludge.

For several years bypass sludge has been packaged and stored as low level mixed waste. As of August 1989, there was an inventory of 1,590 drums (330 m^3) of bypass sludge awaiting disposition as radioactive mixed waste. Rocky Flats estimates that this waste form will continue to be generated at a rate of 153 m^3 per year.

6.1.2 Waste Characterization

As noted above, bypass sludge is generated by the treatment of wastewater in Building 374. The treatment process is designed to precipitate radioactive metals, specifically uranium, plutonium, and americium. The resulting sludge, however, contains not only these materials but also the reaction products of the reagents added to promote the flocculation and precipitation process - ferric sulfate, magnesium sulfate, calcium chloride and a polymeric flocculation agent. This treatment process is not specific to the radioactive metals and co-precipitation of other heavy metals would also be expected to occur. If present, these heavy metals would be expected at low concentrations since there are no major sources for them in the wastewaters entering this portion of the Building 374 treatment facility.

There are only limited analytical data available on the bypass sludge. In August 1988, three samples were taken and analyzed for TCLP Spent Solvents (VOC, methanol, and acid compounds), Volatiles, and Semivolatiles.

The analytical results on each of these categories is described below. Based on these analytical results and process knowledge, EPA Hazardous Waste Numbers that are or may be applicable to this waste will then be provided.

6.1.2.1 TCLP Spent Solvent

The three categories for which TCLP analyses were performed essentially make up the list of F001 through F005 solvents regulated by LDR. In the three samples analyzed, essentially no solvents were found. Acetone and methylene chloride were observed in all three samples but at concentrations consistent with those seen in method and extract blanks (10 to 40 ppb range). The presence of these constituents was discounted. None of the other compounds were detected.

6.1.2.2 Volatiles

Of the 34 volatiles for which analysis was performed, only methylene chloride was detected. It was positive in each of the three samples at an average concentration of 60 ppb. Methylene chloride was also the only volatile showing up in both of the method blanks, but was seen at lower concentrations (19 and 12 ppb). Although questionable, the analytical results do not exclude the possibility of methylene chloride being present at low concentrations.

6.1.2.3 Semivolatiles

The samples were analyzed for 30 semivolatile components, only one of which was observed and that at concentrations below that which could be verified by the analytical measurement technique. That one was hexachlorobenzene. It was reported in each of the three samples, but at concentrations below the analytical measurement limit of 330 ppb. Since the regulatory limit applicable to this material is 1,000 ppm for Halogenated Organic Compounds (HOC), its presence is not considered to be significant.

6.1.2.4 Applicable EPA Hazardous Waste Numbers

Because of the limited analytical data available, some of the applicable EPA Hazardous Waste Numbers are identified as "likely". Additional sampling and analysis for a broader range of constituents will be required to determine whether or not these numbers do indeed apply.

RCRA Characteristics - In its final form the only RCRA characteristic that would be of particular concern is that associated with EP Toxicity. As indicated, the sludge is generated by a process designed to create a floc from metal hydroxides, followed by precipitation and clarification. This is standard treatment for industrial wastewaters contaminated with heavy metals. Although the Building 374 process is optimized for the removal of uranium, plutonium, and americium, co-precipitation of heavy metals would be expected. These heavy metals being concentrated in the sludge cause the concern with respect to EP Toxicity.

Many of the individual waste streams coming to Building 374 from other buildings on plant site were sampled during the Waste Stream Identification and Characterization Program. Several of these streams contained EP Toxic metals. In fact, each of these toxic metals, with the exception of barium and selenium, showed up in at least one waste stream. It is very unlikely that any of them would be in the Building 374 influent at levels approaching EP Toxicity limits because of dilution from other waste streams. However, since they are known to be present and since they would be expected to precipitate to some extent in the treatment process, the following EP Toxic metals are of concern:

Hazardous Waste Number	Description
D004	Arsenic
D006	Cadmium
D007	Chromium
D008	Lead
D009	Mercury
D011	Silver

RCRA Listed Wastes - The listed wastes of concern are F001 to F005 Spent Solvents.

6.1.3 Treatment Alternatives

Treatment alternatives were identified for both the stored solidified sludge and for the material currently being generated.

6.1.3.1 Solidified Bypass Sludge

The stored waste material formed by the sludge and diatomite/cement addition is a friable material that meets the current INEL storage and WIPP disposal criteria. If any of the stored material is analyzed and found not to meet LDR requirements, the material could be size reduced and treated. The following treatments were identified as possible alternatives.

Thermal Treatments

Glass Melter
Microwave Melter
Plasma Arc Furnace

Immobilization Treatments

Lime-Fly Ash Pozzolan
Portland Cement
Polymer Encapsulation

6.1.3.2 Current Generation

The feed material to the bypass sludge process is an aqueous solution. In the past this has been treated and solidified as noted above. It might be possible to treat the feed solution before solidification, however, using ion exchange or solvent extraction. A waste water would be produced that could go directly to the production evaporator. The other aqueous waste stream generated would require some type of an immobilization treatment.

If the feed solutions could not be treated as discussed above, it could be precipitated as is now being done and the sludge treated by a thermal and immobilization process.

Thermal Treatments

Glass Melter
Microwave Melter
Plasma Arc Furnace

Physical Treatments

Ion Exchange
Solvent Extraction

Immobilization Treatments

Lime-Fly Ash Pozzolan
Portland Cement
Polymer Encapulation

6.1.4 Treatment Evaluation

The bypass sludge has not been well characterized. This waste characterization must be done before serious consideration can be given to waste treatment.

If waste characterization shows the stored material does not meet LDR requirements, the material could be size-reduced and treated. Vitrification of the sludge would be energy-intensive but merits further investigation because of the potential reduction in weight and volume. It would also eliminate organics from the solid. Volatilized organics would require off-gas treatment such as an afterburner to destroy the organics, or carbon adsorption (giving a hazardous, but not mixed hazardous waste).

It is more likely that the waste will not contain organics but will have levels of heavy metals above LDR limits. Immobilization in cement is probably the simplest way to treat the bypass sludge and immobilize the heavy metals present. Polymer encapsulation is an efficient immobilization treatment that also should be investigated.

As noted above, physical treatments may be effective in removing metal contaminants from the currently generated aqueous waste streams. Unfortunately, most of the aqueous waste streams sent to precipitation, while low in actinide concentrations, have high concentrations of other ions, e.g., aluminum, sodium, potassium, and nitrate. This could make ion exchange recovery of EP Toxic metals present in low concentrations difficult. Highly salted solutions are more amenable to solvent extraction, but limitations exist here that are both technical and regulatory (the expanded use of solvents may not be permitted). Process development would be required, but this waste category is sufficiently large that substantial efforts to find more efficient ways to treat it are justifiable.

6.2 Soil and Cleanup Debris

6.2.1 Generation Processes

Contaminated soil is generated from the excavation of areas that are contaminated with radioactive materials and RCRA-hazardous constituents. The contamination is the result of spills or leaks of hazardous materials that occurred in the 1960's at the 903 Pad. At that time, drums of waste stored in that area were found to have leaked. The soil and cleanup debris was generated during recent investigative drilling in the 903 Pad area. The contaminated dirt has come from either the drill holes themselves or from sampling in the area of the holes. To date, 9.2 m^3 of contaminated soil waste has been generated and is being stored in six 2 ft. by 4 ft. by 7 ft. boxes (referred to as half boxes). For estimation purposes, it is assumed that this waste will continue to be generated at a rate of approximately 3.1 m^3 per year. This does not include any major soil excavation projects that may occur as a result of remedial or corrective actions.

6.2.2 Waste Characterization

Soil and cleanup debris consists of Rocky Flats soil contaminated with various hazardous constituents. Based on Appendix I of the Part B permit application dated December 15, 1987, the hazardous components are carbon tetrachloride, trichloroethylene, perchloroethylene, and acetone. The acetone is listed as acetone still bottoms.

The soil and cleanup debris is not thoroughly characterized. A sampling and analysis program will be of primary importance.

6.2.3 Treatment Alternatives

Eighteen options listed below have been identified as candidates for treatment of soil and cleanup debris.

Thermal Treatments

Rotary Kiln Incinerator
Infrared Incinerator
Advanced Electric Reactor
Glass Melter
Microwave Melter
Controlled Air Incineration
Plasma Arc Furnace
Oxygen Enhanced Incineration

Chemical Treatments

Catalytic Dehalogenation
Biodegradation

Physical Treatments

Volatilization
Supercritical Fluid Extraction
Solvent Extraction
Air Stripping
Steam Stripping

Immobilization Treatments

Lime-Fly Ash Pozzolan
Portland Cement
Polymer Encapsulation

6.2.4 Treatment Evaluation

Additional waste characterization is required before waste treatment options can be knowledgeably addressed, even though this waste category is not large at present.

Immobilization treatments can be quickly implemented but their effectiveness for organic retention has not been verified. If HOCs are determined to be present, incineration may be the most effective way to volatilize and destroy these organics. An off-gas treatment system would be required to destroy or remove any organics not eliminated during incineration. The resultant soil would be LLW; immobilization by cementation or polymer encapsulation may be required before the waste could be sent to storage, depending on particle size distribution.

If a vitrification process were to be developed for a larger waste category, it would be appropriate to process this smaller amount of waste through that system. Vitrification, in addition to destroying or volatilizing the organic constituents, provides a monolith that encapsulates the radioactives. The vitrification process would produce off-gases requiring secondary treatment.

Biological treatments would destroy organics, but substantial studies would be required to determine the appropriate method (aerobic or anaerobic) and microbial species to perform the work. Catalytic dehalogenation might also destroy the listed organics, but again, considerable development work would be required.

The physical treatment processes listed could also effect removal of HOCs. Volatilization, air stripping, and steam stripping would appear to be the most simple physical approaches. Solvent or supercritical fluid extraction are possible, but appear to be more difficult. Any of the physical methods would require off-gas treatment and possibly immobilization of the resultant LLW soil.

6.3 Cutoff Sludge

6.3.1 Generation Process

Historically, Building 889 has served as a decontamination facility for steam cleaning radiologically-contaminated equipment at RFP. Equipment was brought from various locations in the plant and after cleaning the waste water was transferred to the waste water treatment facility in Building 374.

During upgrading activities in Building 889, the cleaning equipment was removed and sludge material was found in the collection system beneath. Cement was added to the sludge to absorb free liquid and the mixture was placed in two half boxes; this granular mixture is called cutoff sludge. These boxes are in storage awaiting final disposition.

6.3.2 Waste Characterization

Some of the cutoff sludge's characterization are based on process knowledge. The sludge was produced from materials washed off of equipment during decontamination. The type of equipment cleaned varied greatly but included such items as motors and lathes. In addition to radiological contaminants, the equipment cleaned could be expected to contain oils, greases, rust, metal chips, and grindings. Items such as lathes likely contained cutting oils and listed solvents. During the Waste Stream Identification and Characterization Program in 1986 and 1987, the sump in which Building 889 cleaning water collected was sampled and analyzed: it did show moderately high levels of organic solvents. The cutoff sludge was sampled in January 1988 after the addition of cement and analyzed for total metals, volatiles, radioactive components, and pH. These results as well as applicable EPA hazardous waste numbers are given in the following sections.

6.3.2.1 Metals

Analyses of the single cutoff sludge sample indicated the following metals were present.

Metal	Concn, ppm	Metal	Concn, ppm
Aluminum	6,016	Manganese	228
Antimony	41	Mercury	1
Arsenic	7	Molybdenum	29
Barium	176	Nickel	239
Beryllium	8,900	Potassium	3,600
Cadmium	31	Selenium	<1
Calcium	14,732	Silver	6
Chromium	306	Sodium	2,394
Cobalt	Not Detected	Strontium	46
Copper	205	Titanium	<1
Iron	26,449	Vanadium	Not Detected
Lead	1,500	Zinc	464
Magnesium	2,728		

6.3.2.2 Volatiles

The cutoff sludge sample was analyzed for 34 different volatile compounds. Only 12 of those compounds were observed at levels above detection. The volatiles observed and their concentrations are as follows:

Compound	Concn, ppb
Acetone	38
2-Butanone	11
Carbon Tetrachloride	9
1, 1-Dichloroethene	17
1, 2-Dichloropropane	357
Ethylbenzene	11
Methylene Chloride	32
Tetrachloroethane	331
Toluene	44
1, 1, 1-Trichloroethane	19
Trichloroethylene	11
Total Xylenes	34

6.3.2.3 Radiochemistry

The single sample of cutoff sludge had a gross alpha of 3.9 $\pm$ 0.2 X 10^3 pCi/g.

6.3.2.4 pH

The sample had a pH of 8.9.

6.3.2.5 Applicable EPA Hazardous Waste Numbers

As described above, the cutoff sludge waste is an accumulation of materials cleaned off many kinds of equipment from various plant processes. The waste, therefore, could be contaminated with various types of hazardous constituents. Based on the types of activities involved at RFP and the way the waste was generated, EP Toxic metals are the RCRA characteristics that would be suspected and solvents are the RCRA listed wastes that may be present. The analysis of the single sample of sludge supports this. The possibility that equipment from electroplating operations in Building 444 were cleaned in Building 889 also means that the other listed wastes may be present. The specific EPA hazardous waste numbers that may be applicable to the cutoff sludge waste are described below.

RCRA Characteristics - Whether or not cutoff sludge qualifies as a characteristic hazardous waste depends solely on the results of analytical tests performed on the material. The specific analytical test required - the EP Toxicity test - has not been performed, but based on the total metals analyses discussed in section 6.3.2.1, the following EPA Hazardous Waste Numbers may be applicable:

Hazardous Waste Number	Description
D004	Arsenic
D005	Barium
D006	Cadmium
D007	Chromium
D008	Lead
D009	Mercury
D011	Silver

Considering the EP Toxicity analysis method and the dilution that occurs when testing solid samples, it is very unlikely that arsenic, barium, mercury, and silver will exceed the maximum concentrations. However, sampling and analysis for the above metals, using the Extraction Procedure (EP), will be necessary to make the final determination.

RCRA Listed Wastes - Listed wastes suspected to be in cutoff sludge, based on process knowledge, include F001, F002, F003, F005, F007, F008, and F009.

All but two of the volatiles detected in the cutoff sludge are solvents listed under F001, F002, F003, or F005. Since the exact source of those hazardous constituents is unknown, the conservative approach is to assume they are from listed sources. The presence of F007, F008 or F009 waste is speculative at best. If the cutoff sludge is analyzed for cyanide and none is detected, it can probably be assumed that none of the F007 through F009 listed wastes are present.

6.3.3 Treatment Alternatives

The small inventory of cutoff sludge is probably acceptable for land disposal now but in the future such disposal will possibly be unacceptable because of concentrations of EP Toxic metals. EPA has not yet published BDAT treatment standards in the LDR regulations for waste that exceeds EP Toxicity for metals. It is possible that land disposal of RCRA characteristic waste in general will be prohibited. Another possibility, based on BDATs for similar

wastes, is that a limit may be set and stabilization of metals may be the recommended approach to achieve the limit.

Thermal Treatments

Rotary Kiln Incinerator
Infrared Incinerator
Glass Melter
Microwave Melter
Controlled Air Incineration
Plasma Arc Furnace
Oxygen Enhanced Incineration

Physical Treatment

Solvent Extraction

Immobilization Treatments

Lime-Fly Ash Pozzolan
Portland Cement
Polymer Encapsulation

6.3.4 Treatment Evaluation

Additional waste characterization is needed even though the cutoff sludge is a small waste category and no more is being generated.

Immobilization is probably the simplest way to treat the cutoff sludge and to immobilize the heavy metals present. Polymer encapsulation is an efficient immobilization treatment for retaining organics and should be investigated.

Incineration would be a viable method for volatilizing and destroying organics. An off-gas treatment system would be required to treat any organics not destroyed in the incinerator and a scrubber might be needed to remove particulates and cool the off-gas prior to discharge to a HEPA filter system. The solid residue from incineration would require immobilization. Once the organics are gone, cementation would suffice to immobilize the LLW in a form acceptable to NTS.

Vitrification of the sludge would be more energy intensive than polymer encapsulation or the incineration techniques, but merits further investigation because of its potential for destruction of organics plus reduced weight and volume of the final waste form. This method would not be developed specifically for this small amount of waste, but cutoff sludge could be processed through such a facility if one were available and in use for larger amounts of waste, e.g., bypass sludge. Vitrification methods would require off-gas treatment for organics.

Solvent extraction with some non-listed solvent, e.g., tetrahydrofuran (THF), could be used to extract HOCs. This would require subsequent treatment of the THF to remove the HOCs and possibly permit recycle of THF. Immobilization of the sludge would also be required.

6.4 Solidified Organics/TRU

6.4.1 Generation Process

Radioactively contaminated liquid organics, such as hydraulic oils, solvents and lathe coolant, are sent to the Waste Treatment Facility from the metal fabrication areas and development laboratories in Buildings 707, 776, and 777. The liquids are mixed with gypsum cement in 55 gallon drums. The drum is lined with one or two bag liners and a rigid polyethylene liner. This waste was transported to the Idaho National Engineering Laboratory (INEL) in the past for storage. Presently, the drums are moved to a transuranic mixed waste storage area after processing is complete (1).

RFP has several drums of solidified organics that were returned by INEL as part of the INEL Waste Examination Program. These older drums were mixed with calcium silicate to form a grease-like waste.

There are 73 m^3 of solidified organics in storage. It is estimated that this waste form will continue to be generated at a rate of 71 m^3/yr.

6.4.2 Waste Characterization

The cemented sludge may contain solvents which are used to degrease tools or plutonium parts during machining and prior to assembly. A characterization in 1987 reported these solvents may be present in a maximum concentration of 25% in the packaged waste. A single sample of the waste was analyzed for volatiles only in August 1988.

6.4.2.1 Volatiles

Three volatile compounds were detected in the single, analyzed sample. The information obtained is as follows:

Compounds	Concn, ppm
1,2-Dichloroethene	1
1,1,1-Trichloroethane	35
Carbon Tetrachloride	78

The older solidified organics listed in the previous section may contain trichloroethane, carbon tetrachloride, trichloroethylene, tetrachloroethylene, nitrobenzene, and polychlorinated biphenyls (1). Additional sampling will be required to verify the organic constituents.

6.4.2.2 Radiochemistry

No specific data are available. The waste is categorized, however, as transuranic.

6.4.2.3 Applicable Hazardous Waste Numbers

Based on the plant processes generating the organic waste, the Hazardous Waste Number has been determined to be F001.

6.4.3 Treatment Alternatives

Eleven treatment options listed below have been identified as candidates for the solidified organics.

Thermal Treatments

Rotary Kiln Incineration
Infrared Incineration
Glass Melter
Controlled Air Incineration
Plasma Arc Furnace
Oxygen Enhanced Incineration

Chemical Treatments

Biodegradation

Physical Treatments

Volatilization
Solvent Extraction
Air Stripping
Steam Stripping

6.4.4 Treatment Evaluation

Additional waste characterization is needed to determine the level of HOCs present in this waste.

The organic wastes were originally treated to meet both INEL and WIPP disposal requirements. The waste is no longer shipped to INEL for storage but continues to be solidified since WIPP is working to obtain exemptions that would allow acceptance of this waste form. If the exemptions are obtained, the waste will be shipped to WIPP and no further treatment will be required. If RFP discovers that WIPP can not accept this waste, solidification processes may stop and the organics would be treated in a fashion similar to FBI Oil (Section 6.11). However, RFP may be left with a backlog of solidified waste that requires treatment. This treatment evaluation relates only to the solidified waste.

The waste form is a gypsum cement structure that physically contains the emulsified organics. All treatment alternatives would require a crushing pretreatment to reduce the size of the gypsum block. Once crushed, the organics could be destroyed in an incinerator. However, the incinerator would have to handle the large quantity of ash generated as a result of the gypsum cement. The ash generated from an incineration process would require immobilization. The plasma arc furnace and glass melter would also thermally destroy the organics. Either process has the potential to generate a vitreous residue that would not require further immobilization. Any thermal treatment would be energy intensive and require adequate off-gas treatment.

Alternatives to incineration are physical and chemical treatments. The hazardous solvents might also be removed by physical treatments such as volatilization and air or steam stripping. Off-gas treatment would be required to destroy the organics. Once the solvents were removed, the waste would no longer be mixed and could be treated as TRU waste. Solvent extraction might be useful, although this technique would result in an organic stream requiring further treatment as a hazardous waste. This method would require developmental work.

Biodegradation could conceivably be used for this waste. However, significant research and development would be required and it is not apparent that the method would offer any real advantage over previously discussed techniques.

6.4.5 References

(1) R. D. Petersen, Organic and Sludge Immobilization System, RFP 4095, Rockwell International, Golden, CO, July 1987. pp 1-13.

6.5 Combustibles and Filters/TRU

6.5.1 Generation Processes

Mixed TRU combustibles and filters contain radioactive material at concentrations above 100 nCi/g but below the economic discard limit along with organic solvents. These wastes are generated at various locations at Rocky Flats in a wide variety of operations, but come primarily from the cleanup of gloveboxes and spills. After the waste is generated, it is assayed for radioactive content and placed in 55 gallon drums.

6.5.2 Waste Characterization

Mixed TRU combustibles and filters consist of rags, cloth, coveralls, rubber, and wood along with various types of filter media. These filter media include activated carbon, cartridge, and HEPA's. The filters are commonly constructed of combustible materials such as wood, rubber, and plastic, but may also contain metal components. Based on knowledge of the operations which produced these wastes, the hazardous components are organic solvents, specifically 1,1,1-trichloroethane, 1,1,2-trichloro-1,2,2-trifluoroethane, methylene chloride, and acetone/toluene/methyl ethyl ketone mixtures. A total characterization of this waste form has not been completed.

TRU combustibles and filters are presently being generated at a rate of 515 m^3/yr. A total of 257 m^3 is presently stored at Rocky Flats in permitted storage areas.

6.5.3 Treatment Alternatives

Twenty treatment options listed below have been identified as candidates for TRU mixed combustibles and filters.

Thermal Treatments

Rotary Kiln Incinerator
Infrared Incinerator
Glass Melter
Controlled Air Incineration
Wet Air Oxidation
Cyclone Incinerator
Plasma Arc Furnace
Fluidized Bed Incineration
Oxygen Enhanced Incineration

Chemical Treatments

Acid Digestion
Biodegradation

Physical Treatments

Aqueous Wash
Volatilization
Supercritical Fluid Extraction
Solvent Extraction
Air Stripping
Steam Stripping

Immobilization Treatments

Lime-Fly Ash Pozzolan
Portland Cement
Polymer Encapsulation

6.5.4 Treatment Evaluation

Incineration is a well developed method for destroying mixed TRU combustibles and filters and the hazardous organic materials contained in this waste. An advantage of incineration is a factor of ten reduction in volume. Shredding would be required in the case of fluidized bed incineration, but this disadvantage would be partially offset, at least, in that organics would be destroyed and acids neutralized in the bed. Residual ash and off-gases from incineration would require further treatment.

Vitrification techniques would also require off-gas treatment, but the residuals would be encapsulated in glass. Wet air oxidation is another thermal treatment method that could be developed for combustibles and filters,

but little has been done to date since incineration has proven so effective historically.

Acid digestion and biodegradation could possibly be effective, but a considerable development effort would be required. Residuals would require immobilization.

Physical treatments should not be disregarded. The combustibles and filters could be washed with water to remove organic contaminants. The major drawback with this technique is that an aqueous waste contaminated with HOCs must now be treated, and wet combustibles must also be treated. Volatilization, air stripping, and steam stripping could also remove the organics; an off-gas treatment system would be required, and the combustible residuals would still require immobilization. Supercritical fluid and solvent extraction could also be used; again, combustible residuals would remain.

Immobilization is probably the simplest method to treat the combustibles and filters. Polymer encapsulation is an efficient immobilization treatment which would fix the organic constituents. Cementation could be used on combustibles and filters once the organics have been removed. Shredding would be required with all immobilization techniques. A substantial waste volume increase penalty is paid if immobilization of unburned combustibles is done rather than immobilization of residual ash.

6.6 Metal/TRU

6.6.1 Generation Processes

This waste form includes items such as machinery, gloveboxes, empty containers, etc. The items that are difficult to reduce to a size that fit in a 55 gallon drum are placed in a DOT 7A, Type A metal box.

6.6.2 Waste Characterization

Process knowledge was used to characterize this waste in 1987 to determine if any Reportable Quantities per 49-CFR-72 were present. The hazardous constituents listed then were 1,1,1-trichloroethane, carbon tetrachloride, 1,1,2-trichloro-1,2,2,-trifluoroethane, methylene chloride, and lead. The first three halogenated organics are degreasing agents. Methylene chloride is a paint remover. Discarded radiation shielding accounts for the lead in the waste. The non-solvent and solvent-contaminated metals are not segregated. This results in all waste being considered RCRA regulated and LDR. A waste characterization program will be important prior to treatment.

6.6.3 Treatment Alternatives

Seventeen treatment options were identified as candidates for TRU metals.

Thermal Treatments

Rotary Kiln Incinerator
Infrared Incinerator
Controlled Air Incineration
Plasma Arc Furnace
Metal Melter
Oxygen Enhanced Incineration

Chemical Treatments

Electrodecontamination
Chemical Reduction-Oxidation
Acid Leaching

Physical Treatments

Aqueous Wash
Volatilization
Supercritical Fluid Extraction
Air Stripping
Steam Stripping

Immobilization Treatments

Lime-Fly Ash Pozzolan
Portland Cement
Polymer Encapsulation

6.6.4 Treatment Evaluation

In addition to waste characterization, pretreatment such as physical sorting or shredding will be required prior to any treatment.

Incineration of the size-reduced metal would destroy organics or volatilize them for subsequent destruction or removal in an off-gas treatment system. Lead, usually present as glovebox shielding, should be removed prior to thermal treatments above its melting point; otherwise it may be present in the off-gas as an aerosol. The plasma arc furnace and metal melter would both destroy or volatilize organics as well as reduce the volume of the bulk metal requiring immobilization.

Chemical treatments could be used to destroy organics and to remove enough radioactive contamination to permit the metal to be treated as LLW. (This is not an important consideration with respect to mixed waste considerations, but is important for storage costs; LLW storage is less costly than TRU waste storage.)

Physical treatment methods such as aqueous wash, volatilization, supercritical fluid extraction, and air or steam stripping could be used to remove organics; in each case one or more secondary organic-bearing waste streams result.

The TRU-contaminated metal can be cemented once organics have been removed. As noted previously, polymer encapsulation might be able to immobilize both the organic and radioactive contaminants.

6.7 Aqueous Sludge/TRU

6.7.1 Generation Processes

The aqueous wastes from the Building 771 plutonium recovery area are treated in a hydroxide precipitation process to remove heavy metallic elements. The resultant slurry is passed through a rotary drum vacuum filter precoated with diatomaceous earth filter medium, to remove the solids from the waste stream. A thin layer of filter cake is continuously cut from the drum filter, producing a wet sludge. In the present operation a Portland cement/diatomite mixture is added to the waste container along with the filter cake to absorb free liquids (1).

Aqueous precipitation sludge has been packaged and stored as TRU mixed waste. As of August 1989, there was an inventory of 579 drums (159 m^3) of precipitation sludge awaiting disposition as transuranic mixed waste. It is estimated that this waste form will continue to be generated at a rate of 111 m^3/yr.

6.7.2 Waste Characterization

As noted above, aqueous precipitation sludge is generated from the treatment of Building 771 plutonium recovery waste in Building 774. The treatment process is designed primarily to precipitate radioactive metals, specifically uranium, plutonium, and americium. In addition, the sludge contains chemicals added to promote the flocculation and precipitation process (ferric hydroxide, magnesium hydroxide, calcium sulfate, and a polymeric flocculation agent). This treatment process is not specific to the radioactive metals and co-precipitation of heavy metals would also be expected to occur. If present, these would be expected at low concentrations since there are no major source of the heavy metals in the wastes entering this portion of the Building 774 treatment facility.

There are only limited analytical data available on the uncemented aqueous precipitation sludge. In April 1988, samples were taken and analyzed for Appendix III Volatiles. The analytical results are described in the following paragraphs. Based on the analytical results and process knowledge, EPA Hazardous Waste Numbers that are or may be applicable to this waste are also given.

6.7.2.1 TCLP Spent Solvent

No TCLP tests were conducted on the TRU aqueous precipitation sludge.

6.7.2.2 Appendix III Volatiles

Of the volatiles for which analysis was performed the following were found above detection limits: methylene chloride, chloroform, 1,1,1-trichloroethane, carbon tetrachloride, trichloroethylene, trans-1,3-dichloropropene, 1,1,2,2-tetrachloroethane, toluene, ethylbenzene, styrene, and xylene.

6.7.2.3 Appendix III Semivolatiles

No semivolatile analyses were performed.

6.7.2.4 Applicable Hazardous Waste Numbers

The applicable EPA Hazardous Waste Numbers will be quite similar to those of bypass sludge. Sampling and analysis for constituents will be required to verify whether these numbers apply.
RCRA Characteristics - In its final form (damp sludge with adsorbents added), the only RCRA characteristic that would be of particular concern is that

associated with EP Toxicity. As mentioned previously, the major process contributing to the generation of this material is a wastewater treatment process designed to create a floc from metal hydroxides, followed by precipitation and clarification. This is standard treatment for industrial wastewaters contaminated with heavy metals. Although the Building 774 process is optimized for the removal of uranium, plutonium, and americium, co-precipitation of other heavy metals would be expected. The heavy metals being concentrated in the sludge that cause concern with respect to EP Toxicity are D006, cadmium, and D008, lead.

RCRA Listed Wastes - The listed wastes found in the analyses are spent solvents covered by Hazardous Wastes Numbers F001 through F005.

6.7.3 Treatment Alternatives

Treatment alternatives were identified for both the stored aqueous sludge and for the material currently being generated.

6.7.3.1 Solidified Aqueous Sludge

The stored waste material formed by the sludge and diatomite/cement addition is a friable material that meets the current INEL storage and WIPP disposal criteria. If any of the stored material is analyzed and found not to meet LDR requirements, the material could be size reduced and treated. The following treatments were identified as possible alternatives.

Thermal Treatments

Glass Melter
Microwave Melter
Plasma Arc Furnace

Immobilization Treatments

Lime-Fly Ash Pozzolan
Portland Cement
Polymer Encapsulation

6.7.3.2 Current Generation

The feed material to the sludge process is an aqueous solution. In the past this has been treated and solidified as noted above. It might be possible to treat the feed solution before solidification, however, using ion exchange or solvent extraction. A waste water would be produced that could go directly to the production evaporater. The other aqueous waste stream generated would require some type of an immobilizaton treatment.

If the feed solutions could not be treated as discussed above, it could be precipitated as is now being done and the sludge treated by a thermal and immobilizaton process.

Thermal Treatments

Glass Melter
Microwave Melter
Plasma Arc Furnace

Physical Treatments

Ion Exchange
Solvent Extraction

Immobilization Treatments

Lime-Fly Ash Pozzolan
Portland Cement
Polymer Encapsulation

6.7.4 Treatment Evaluation

The TRU aqueous sludge has not been well characterized. A sampling and analysis program to do this will be important to accurately define sludge composition. But based on the limited analytical information available, and on knowledge of the process, the sludge will probably contain levels of heavy metals above LDR limits. TRU aqueous sludge is very similar to bypass sludge except the latter is LLW.

If waste characterization shows the stored material does not meet LDR requirements, the solidified sludge could be size-reduced and treated. Vitrification of the sludge would be energy intensive but merits investigation because of the potential weight and volume reduction. It would also eliminate organics from the solid. The off-gas would require treatment to ensure organic destruction or adsorption.

As in the case of bypass sludge, it is likely the waste will not contain HOCs but will contain levels of heavy metals above LDR limits. Immobilization in cement is probably the simplest way to treat the sludge and to immobilize the heavy metals present. Polymer encapsulation should be more thoroughly investigated; it has the potential of providing a waste form of lower metal leachability and retaining organics if such prove to be present.

As discussed, physical treatments may be effective in removing contaminants from the currently-generated aqueous waste stream before the precipitation step. Unfortunately, most of the aqueous waste streams sent to precipitation in Building 774 have high concentrations of aluminum, sodium, potassium, and nitrate. This could make ion exchange recovery of EP Toxic metals present in low concentrations difficult. Highly salted solutions are more amenable to solvent extraction, but technical and regulatory limitations also cast doubt on this technique. Process development would be required, but this waste category is large and still being generated. Efforts should be made to find more efficient ways to dispose this waste.

6.7.5 Reference

(1) R. D. Petersen and A. J. Johnson, Application of Microwave Energy for In-Drum Solidification of Simulated Precipitation Sludge, RFP 4148, Rockwell International, Golden, CO, August 1987.

6.8 Miscellaneous Wastes/TRU

6.8.1 Generation Processes

Miscellaneous waste consists of plutonium-contaminated Raschig rings and blacktop, concrete, dirt, and sand along with various hazardous constituents. The hazardous constituents are 1,1,1-trichloroethane, carbon tetrachloride, 1,1,2-trichloro-1,2,2-trifluoroethane, and methylene chloride.

Once the waste is generated, it is usually packaged into 55 gallon drums with multiple bag liners, a fiberboard liner, and a rigid polyethylene liner. Also, this waste can be packaged in DOT 7A, Type A metal boxes which are lined with a fiberboard and PVC liner.

6.8.2 Waste Characterization

The miscellaneous wastes are not well characterized. A waste characterization program will be required to enable knowledgeable decisions on prospective treatment methods.

Miscellaneous waste is presently being generated at 0.4 m^3/month. A total of 3.0 m^3 miscellaneous waste is presently stored at Rocky Flats in permitted storage areas.

6.8.3 Treatment Alternatives

Seventeen treatment options listed below have been identified as candidates for miscellaneous wastes.

Thermal Treatments

Rotary Kiln Incinerator
Infrared Incinerator
Advanced Electric Reactor
Glass Melter
Microwave Melter
Controlled Air Incineration
Plasma Arc Furnace
Oxygen Enhanced Incineration

Chemical Treatments

Acid Digestion
Biodegradation

Physical Treatments

Volatilization
Supercritical Fluid Extraction
Air Stripping
Steam Stripping

Immobilization Treatments

Lime-Fly Ash Pozzolan
Portland Cement
Polymer Encapsulation

6.8.4 Treatment Evaluation

Additional waste characterization is needed even though this waste category is not large at present.

The comments in Section 2.4 also apply to this waste. The Raschig rings are not a complication, but asphalt can give problems (coking) in incineration unless a high-temperature, oxygen-enhanced incineration process is used. For this reason, segregation might be required, with subsequent immobilization of the asphalt.

Immobilization techniques can be quickly implemented but their effectiveness for organic retention is suspect. If HOCs are present in amounts requiring treatment, incineration may be the most effective treatment. An

off-gas treatment system would be required to destroy or remove any organics not eliminated during incineration. The resultant soil, concrete, and Raschig rings would be TRU waste; immobilization by cementation or polymer encapsulation would be required before the waste could be sent to storage.

If a vitrification process were available for a larger waste category, it would be appropriate to process this smaller amount of waste through that system. Vitrification , in addition to destroying or volatilizing the organic constituents, provides a monolith that encapsulates the radioactives. The vitrification process would produce off-gases requiring secondary treatment.

Biodegradation could destroy organics but a substantial development effort would be required to determine the appropriate method (aerobic or anaerobic) and microbial species to perform the work. Acid digestion is included in case elimination of the asphalt by some means other than sorting and immobilization is desired.

The physical treatment processes listed could also effect removal of HOCs. Volatilization, air stripping, and steam stripping would appear to be the most simple physical approaches. Solvent or supercritical fluid extraction are possible, but appear to be more difficult. Any of the physical methods would require off-gas treatment and immobilization of the resultant TRU waste.

6.9 Particulate-Sludge Wastes/TRU

6.9.1 Generation Processes

Particulate-sludge waste is composed of spent ion exchange resins from plutonium recovery operations. The resins are discarded when the buildup of fine resin fragments begins to restrict solution flow. The plutonium is then eluted with 0.35 N HNO_3 before the resin is removed from the production columns. After removal, the resin is packed into plastic lined cardboard

tubes (approximately 6" x 24"). The resin in the tube is washed with water to remove residual nitric acid and stored, one tube per 55 gallon drum.

6.9.2 Waste Characterization

The characterization of this waste is questionable. The Rocky Flats Part B permit application for TRU mixed waste indicates that ion exchange resins contain solvents. This designation may be in error, because there is no evidence for the source of the solvents. No laboratory analysis of this waste has been conducted for RCRA constituents. The resins may also be contaminated with heavy metals but the analysis for these are lacking as well.

Currently there is a sampling program being conducted to better characterize this waste stream. As a result of this program, this waste stream may be reclassified.

Particulate-sludge waste is presently being generated at a very slow rate. A total of 16 m^3 of the waste is currently being stored.

6.9.3 Treatment Alternatives

Twelve treatment options have been identified as candidates for particulate-sludge wastes.

Thermal Treatments

Rotary Kiln Incinerator
Infrared Incinerator
Glass Melter
Controlled Air Incineration
Cyclone Incinerator
Plasma Arc Furnace
Fluidize Bed Incineration
Oxygen Enhanced Incineration

Chemical Treatments

Acid Digestion

Immobilization Treatments

Lime-Fly Ash Pozzolan
Portland Cement
Polymer Encapsulation

6.9.4 Treatment Evaluation

As with all of the other wastes, a characterization program is needed to determine if this waste actually has RCRA constituents.

Incineration will destroy particulate-sludge waste. The ash produced would require immobilization and the off-gases might need treatment to remove any oxide aerosols generated during incineration. Incineration is probably the best method for destroying this waste. There is not a great deal of this waste in storage and it is generated slowly, so it could be easily handled in virtually any incinerator available. The small amount of residual ash (these resins are organic resins made of polystyrene-divinylbenzene) could be immobilized in cement or polymer. Vitrification, again if available for a larger waste stream, could also be used to eliminate this waste and would provide a glass monolith.

Acid digestion has also been used to process spent ion exchange resins.

New resins made of polyvilylpyridine are undergoing tests. These resins are more resistant chemically and mechanically and may not require replacement as frequently. This would result in a lowered generation rate.

6.10 Roaster Oxide

6.10.1 Generation Process

Roaster oxide is no longer being generated as mixed waste. It was produced by roasting uranium machining chips which were contaminated with cutting oil and various halogenated organic solvents. The solvents were used to wash the oil from the chips. Presently, an aqueous wash is used to remove the cutting oil. The uranium, after processing, is not pyrophoric and the final waste form generated is non-hazardous.

Depleted uranium chips are roasted in one of two roasters. The old roaster was a multiple hearth furnace with four hearths. The chips readily sustained combustion once ignited. The oxidized uranium was then collected in drums at the bottom of the roaster.

The new chip roaster is a rotary kiln. Uranium chips are fed into a hopper and through a shredder into a vat of water to remove the machining coolent and lubricant. A conveyor transfers the chips from the vat into the calciner which is a downward sloping tube with baffles for mixing. As with the old roaster, heat is added at first, but combustion is self-sustaining from that point.

The roaster oxide is collected in 30-gallon drums which are in turn placed into 55-gallon drums. That waste, which is also hazardous by definition (when listed solvents were used in the generation), has been stored in Building 884 and the 904 Pad cargo containers. Because it is designated a radioactive mixed waste, no off-site facilities have been available for disposal. Approximately 400 drums (84 m^3) are currently being stored. As mentioned previously, this waste is no longer being generated so this inventory is not growing.

6.10.2 Waste Characterization

The roaster oxide waste has not been sampled, but process knowledge allows a fairly complete characterization. As generated, the uranium chip, machining lubricant and coolant, and solvent mixture qualifies as ignitable (D001) because of the pyrophoric uranium metal and is listed (F001) because of the solvents 1,1,1-trichloroethane and 1,1,2-trichloro-1,1,2-trifluoroethane (Freon TF) used for degreasing the metal. The cutting oils and coolants used in the machining process are not hazardous according to RCRA definitions. This was substantiated from the analysis of samples taken during the Waste Stream Identification and Characterization Program in 1987.

As the waste moves toward the roasting process, it is washed, as noted above, but does not lose either of its RCRA waste numbers. The roaster process does, however, eliminate the ignitability characteristic. It is expected that after washing and roasting, the uranium oxide has very little, if any, detectable solvent residue. However, as a matter of definition, the material will retain the Hazardous Material Number, F001, until a sampling and analysis program proves the absence of listed solvents.

6.10.3 Treatment Alternatives

Currently there are no alternatives being considered for additional treatment of the stored inventory of roaster oxide waste. Roasting the waste to eliminate the pyrophoric characteristic should have destroyed the F001 through F005 solvents. The form in which the waste currently exists should meet all applicable LDRs and be suitable for disposal. Once a disposal facility (likely NTS) is ready to accept this mixed waste, it will be shipped.

However, if sampling shows that it can not meet LDR requirements, the following treatments may be applicable.

Thermal Treatments

Rotary Kiln Incinerator
Infared Incinerator
Microwave Melter
Controlled Air Incineration
Plasma Arc Furnace
Oxygen Enhanced Incineration

Physical Treatments

Aqueous Wash
Volatilization
Supercritical Fluid Extraction
Solvent Extraction
Air Stripping
Steam Stripping

Immobilization Treatments

Lime-Fly Ash Pozzolan
Portland Cement
Polymer Encapsulation

6.10.4 Treatment Evaluations

If sampling and analysis show that the waste can be land disposed, it can be shipped to a disposal site. At present, roaster oxide is exempted from immobilization. Sould this be changed, Portland cement, lime-fly ash pozzolan, or polymer encapsulation could be used for the immobilization.

If the waste can not be land disposed, any of the incineration processes noted above could be used to remove the organics. Off-gas treatment would be required for the incineration process, either an afterburner to destroy organics or a carbon bed to adsorb organics, and a system to remove particulates from the off-gas stream. The latter would involve scrubbing and HEPA filtration as currently used at RFP. Any of the immobilization processes noted above could be used.

Physical treatments are also possible for organic removal. Volatilization and air stripping would probably be easiest. Supercritical fluid or solvent extraction, with carbon dioxide or tetrahydrofuran, respectively,

might also work. Steam stripping and aqueous washing would leave a more difficult residue to process, and all of these methods would require treatment of the off-gas and/or extractant.

6.11 FBI Oil

6.11.1 Generation Process

Various operations within RFP generate waste oil that is contaminated with both hazardous and radiological constituents. This oil has been accumulated and stored at Building 774 with the intent of treatment through incineration in the Fluidized Bed Incinerator (FBI). Hence, the reference to this material as the FBI Oil.

Over 28,000 gallons of waste oil has been accumulated. The primary storage is in two 10,000 gallon tanks. One of the tanks is completely full and locked, the other has some capacity left. The remaining inventory of FBI Oil is being stored in drums inside buildings or cargo containers at various plant locations. The oil is currently being generated at the rate of 4700 gal/yr.

6.11.2 Waste Characterization

The FBI Oil has been mixed as it has accumulated in the two 10,000 gallon tanks. The full, locked tank has been sampled twice, once as part of the Waste Stream Identification and Characterization Program in 1986, and again in 1988. The results of these analyses are given below. The variability in many of the analytical results indicates an inhomogeneous material. Oil is very likely stratified because of entrained solids and water. Additional sampling and analyses will be necessary to determine if stratification exists and, if so, its effect on subsequent treatments.

6.11.2.1 Volatiles

Nine compounds were detected in at least one of the samples as shown in the following table.

Compounds	Concentration, ppb 9/86 Sample	4/88 Sample
1,1-Dichloroethane		24
Chloroform	40	
1,1,1-Trichloroethane	8,000	1,374
Carbon Tetrachloride		200
Trichloroethane	30	
1,1,2-Trichloro-1,2,2,-Trifluoroethane*	7,900	154
1,1,2,2-Tetrachloroethane	10	
Toluene		1,044
Ethylbenzene		424

* Freon TF

6.11.2.2 Semivolatiles

No semivolatiles were observed in either sample.

6.11.2.3 Metals

The metals found in the single sample analyzed, and the concentration of each, are as follows.

Metal	Concn, ppm	Metal	Concn, ppm
Aluminum	26	Manganese	3
Antimony	<2	Mercury	<1
Arsenic	<1	Molybdenum	Not detected
Barium	11	Nickel	4
Beryllium	6	Potassium	305
Cadmium	<1	Selenium	<1
Calcium	230	Silver	Not detected
Chromium	6	Sodium	692
Cobalt	1	Strontium	1
Copper	6	Titanium	<1

Metal	Concn, ppm	Metal	Concn, ppm
Iron	82	Vanadium	Not Detected
Lead	92	Zinc	70
Magnesium	57		

6.11.2.4 Radiochemistry

Radiochemical analyses were performed on both samples, but not for all the same nuclides. The results of the analyses are as follows:

	Concentration, pCi/L	
Analysis	9/86 Sample	4/88 Sample
Gross Alpha	44,000 ± 2,000	55,000 ± 4,000
Gross Beta	16,000 ± 1,000	
Pu-239	220 ± 30	10,000 ± 1,000
U-233,234	29,000 ± 1,000	
U-238	21,000 ± 1,000	
Uranium (Total)		46,000 ± 7,000
Tritium	400 ± 220	

6.11.2.5 RCRA Characteristics

Ignitability - The single test gave a flash point of 49.2°C. This qualifies the oil as ignitable.

Corrosivity - The oil has a pH of 5.9. It is therefore noncorrosive.

EP Toxic Metals - The single sample analyzed for EP Toxic metals indicated that only lead exceeded the limit at a measured concentration of 200 ppm.

6.11.2.6 Other Characteristics

Several other characteristics were investigated for one of the samples with the following results:

Test	Result
Total Chloride	0.224 wt %
Specific Gravity at 25°C	0.8869
Heat Content	22,168.5 ± 1,872.8 BTU/lb
Viscosity at 100°F	210.4 ± 1.4 SUS

6.11.2.7 Applicable EPA Hazardous Waste Numbers

FBI Oil is generated from a variety of processes. Because of this, the individual batches would be expected to have varying characteristics. Just how varied would have to be determined by additional sampling. But based on the data available, the following Hazardous Waste Numbers would be applicable.

RCRA Characteristics - The hazardous waste characteristics applicable to FBI Oil are D001 and D008.

The processes in which much of the oil is generated leads to the potential for general metal contamination. The available data show only lead exceeding RCRA characteristic limits, but the total metal analytical data suggest that other metals could exceed the limits on some batches of oil. Additional samples and analyses for EP Toxic metals would likely be required to insure that D008 is the only number that is applicable.

RCRA Listed Wastes - During cleaning/degreasing activities, the oils are contaminated with hazardous materials. This process knowledge is the primary reason this waste is considered hazardous. The applicable Hazardous Waste Numbers are F001, F002, F003 and F005.

Again, additional sampling of the accumulated oil will be required to better characterize the concentration of individual solvents present. However, it is unlikely that solvents requiring additional Hazardous Waste Numbers will be identified.

6.11.3 Treatment Alternatives

Twenty treatment options listed below have been identified as candidates for FBI Oil.

Thermal Treatments

Rotary Kiln Incinerator
Infrared Incinerator
Advanced Electric Reactor
Glass Melter
Controlled Air Incineration
Wet Air Oxidation
Cyclone Incinerator
Liquid Injection Incineration
Plasma Arc Furnace
Fluidized Bed Incineration
Oxygen Enhanced Incineration

Chemical Treatments

Acid Digestion
Biodegradation
Chemical Reduction-Oxidation

Physical Treatments

Volatilization
Filtration
Distillation
Air Stripping
Centrifugation

Immobilization Treatments

Organic Solidification

6.11.4 Treatment Evaluation

Incineration is the treatment process recommended by EPA for destroying mixed, low level oils. Prior to incineration, however, the FBI Oil should be centrifuged to remove solvents, entrained water, and suspended solids. It is possible that centrifugation could significantly decrease the concentration of

heavy metals in the oil; FBI Oil centrifugation will be considered as a possible mode of treatment.

The light fraction from the centrifugation, which would contain organic solvents, could be incinerated. The oil fraction could also be incinerated. The heavy fraction, which would be primarily water containing whatever solids are present in the oil, could probably be sent to the plant waste treatment facility.

Whatever incineration technique was used would require an off-gas treatment system to remove particulates. Ash produced by incineration would need to be immobilized. The process used could be selected from general cementation processes or polymer encapsulation.

Wet air oxidation is also included in the list of possible treatments although this is generally used for solutions containing no more than 20 vol % organics.

The glass melter and plasma arc furnace are also candidate treatment technologies, although these are both more highly energy-intensive than incineration and the plasma arc furnace is still in development.

The physical treatments listed could have application for selective removal of individual constituents, such as filtration for removal of the radioactive portion and disposal of the remaining oil as a non-mixed waste, or as part of a pretreatment process for a subsequent thermal or chemical treatment. Acid digestion, biodegradation, and chemical reduction-oxidation techniques may also have some use, although given the amount of waste to be processed it is difficult to conceive how these treatments might be used.

Organic solidification is also a possibility. This method would involve addition of commercial (proprietary) products to solidify FBI Oil. Some of these are calcium sulfate-based gypsum cement or a mixture of silicates. The gypsum cement forms a monolithic structure with some strength and retains the

oil, but solvent retention is poor. The silicates form a softer monolith with a pasty consistency. This method also appears to be inferior to incineration, but is included for the sake of completeness.

6.12 Combustibles

6.12.1 Generation Process

Combustibles are generated at numerous locations throughout RFP and include such materials as paper, cloth and plastics. The material is contaminated at low concentrations with depleted uranium and plutonium through contact during manufacturing and related processes. The waste is also considered hazardous because of co-contamination with solvents that are also used in the manufacturing process. The materials making up this waste are items that have been used to wipe off products being machined, cleaned or otherwise handled.

Since the waste is generated at numerous RFP locations from multiple processes, the waste form will vary from drum to drum. In all cases, however, the intent has been to segregate those materials that would be considered combustible. In general, segregation practices within the Perimeter Security Zone (PSZ) of the plant are more rigorous than outside the zone. Occasionally drums of combustibles generated outside the PSZ contain some glass and metals.

As a mixed, low-level waste, there are currently no off-site treatment, storage, or disposal facilities available to accept this waste. As of early August 1989, RFP had accumulated 349 drums (73 m^3) of this combustible waste and continues to generate it at a rate of approximately 150 drums (31 m^3) per year. The 55-gallon drums containing combustible wastes are being stored in Buildings 776 and 884.

6.12.2 Waste Characterization

The combustible waste has had only limited sampling for hazardous constituents: its characterization has been primarily based on process knowledge. The waste is considered radioactive and hazardous because of the materials with which it comes in contact. Solvents used to clean radioactive materials (primarily uranium and plutonium) are wiped off or otherwise contacted by the combustible materials making up this waste stream.

The organic compounds most often found are 1,1,1-trichloroethane, methylene chloride, and 1,1,2-trichloro-1,2,2-trifluoroethane. Because of the nature of the processes (small quantities of solvent wiped or contacted with otherwise clean materials) combined with the volatility of the solvents, it is expected that concentrations of the solvents in the waste form will be small. By definition, however, the RCRA hazardous designation accompanies the waste independent of hazardous constituent concentrations.

Limited sampling of combustibles was done in 1986 and 1987 as part of the RFP Waste Stream Identification and Characterization Program. The results are given below.

6.12.2.1 Volatiles

Thirteen volatile organic compounds were present above detection limits in one or more of the 14 samples analyzed. The analytical results are summarized as follows:

Compound	No. of Samples in which Detected	Average Concn, ppb	Concn Range, ppb
Methylene Chloride	10	883	120 - 2400
Toluene	4	286	32 - 750
Chloroform	4	297	29 - 620
1,1-Dichloroethane	1	53	
Total Xylenes	5	3937	15 - 18000
Trichlorofluoroethane	1	61	
1,2-Dichloropropane	1	73	

Compound	No. of Samples in which Detected	Average Concn, ppb	Concn Range, ppb
Acetone	8	2000	130 - 6800
1,1,2-Trichloro-1,2,2-Trifluoroethane	3	2043	130 - 3800
2-Butanone	2	3715	130 - 7300
Ethylbenzene	1	410	
Trichlorofluoromethane	1	340	
1,1,1-Trichloroethane	1	3700	

6.12.2.2 Semi-Volatiles

Only one semivolatile compound was above the detection limit in either of the two samples analyzed. It was di-n-octyl phthalate at an average concentration of 20,000 ppb.

6.12.2.3 Metals

Only one sample was analyzed for metals. The results are summarized as follows:

Metals	Concn, ppm
Aluminum	37
Antimony	171
Arsenic	4
Cadmium	4
Chromium	36
Cobalt	17
Copper	8
Iron	2390
Lead	64
Manganese	80
Nickel	11
Potassium	1270
Selenium	2
Silver	20
Zinc	3

6.12.2.4 Radiochemistry

Seven samples were analyzed for radioactivity and radionuclides. The results are summarized as follows:

Component	Av Concn pCi/g	Concentration Range, pCi/g
Gross Alpha	211	0.3 - 1400
Gross Beta	304	0.1 - 2100
Pu-239	1.0	0 - 7.2
Am-241	0.6	0 - 0.4
U-233, 234	18.9	0.01- 130
U-238	159	0.05- 1100
Tritium	0.74 pCi/ml	0 - 3.1 pCi/ml

The 95% confidence interval was ± 100 pCi/g when the values were in the thousands and ± 10 pCi/g when the values were in or near the hundreds. For tritium, the interval was ± 0.25 pCi/ml.

6.12.2.5 RCRA Characteristics

Ignitability - One sample was analyzed for ignitability. It was above the 60°C flash point limit.

Reactivity - As a measure of reactivity, one sample was analyzed for its reactive sulfide and cyanide concentrations (different from total sulfide and cyanide concentrations). Sulfide concentration was found to be below the detection limit. The cyanide concentration was 375 ppm. The current EPA action level for reactive cyanide is 250 ppm.

EP Toxic Metals - Only one out of four samples analyzed for EP Toxic Metals had a metal above the detection limit. It was mercury with a concentration of 51 ppm. The EP Toxic limit is 0.2 ppm.

6.12.2.6 Applicable EPA Hazardous Waste Numbers

Combustibles are generated at numerous locations throughout the plant and types vary from drum to drum. This waste has been characterized by process knowledge with limited sampling. Since there is also considerable variability in the concentration of the waste in each drum, it is difficult to get good representative samples. The following hazardous waste designations, therefore, are based on process knowledge as well as analytical results.

RCRA Characteristics - Whether or not combustibles qualify as a characteristic waste depends entirely on individual analytical tests performed on the material in the various drums. Based on the Section 6.12.2.5 results, EPA Hazardous Waste Numbers D003 (reactivity) and D009 (mercury) apply to the combustibles.

Additional sampling and analyses for EP Toxic metals and reactivity would likely be required to ensure that D003 and D009 are applicable, since the designations are based on results of only one sample.

RCRA Listed Wastes - The primary reason for this waste to be considered mixed is the process knowledge that it is contaminated with listed solvents and low concentrations of depleted uranium and plutonium from manufacturing processes. The applicable Hazardous Waste Numbers are F001, F002, F003, and F005.

Additional sampling of the combustibles will be required to better characterize the concentrations of solvents present in each drum of waste.

6.12.3 Treatment Alternatives

Since it is uncertain whether the combustible waste exceed LDR standards, the need for treatment is also uncertain. In addition, the ability to obtain representative samples will be difficult because of the manner in which the waste is generated. Solvent concentrations in the waste will likely vary significantly based upon factors such as the specific item being cleaned and the individual performing the work. Until sampling is performed, it will be

assumed that treatment is necessary.

6.12.3 Treatment Alternatives

Twenty treatment options have been identified as candidates for combustibles.

Thermal Treatments

Rotary Kiln Incinerator
Infrared Incinerator
Glass Melter
Controlled Air Incineration
Wet Air Oxidation
Cyclone Incinerator
Plasma Arc Furnace
Fluidized Bed Incineration
Oxygen Enhanced Incineration

Chemical Treatments

Acid Digestion
Biodegradation

Physical Treatments

Aqueous Wash
Volatilization
Supercritical Fluid Extraction
Solvent Extraction
Air Stripping
Steam Stripping

Immobilization Treatments

Lime-Fly Ash Pozzolan
Portland Cement
Polymer Encapsulation

6.12.4 Treatment Evaluation

Incineration is a well developed method for destroying mixed TRU combustibles and filters and the hazardous organic materials contained in this waste. An advantage of incineration is a factor of ten reduction in volume. Shredding would be required in the case of fluidized bed incineration, but this disadvantage would be partially offset, at least, in that organics would

be destroyed and acids neutralized in the bed. Residual ash and off-gases from incineration would require further treatment.

Vitrification techniques would also require off-gas treatment, but the residuals would be encapsulated in glass. Wet air oxidation is another thermal treatment method that could be developed for combustibles and filters, but little has been done to date since incineration has proven so effective historically.

Acid digestion and biodegradation could possibly be effective, but a considerable development effort would be required. Residuals would require immobilization.

Physical treatments should not be disregarded. The combustibles and filters could be washed with water to remove organic contaminants. The major drawback with this technique is that an aqueous waste contaminated with HOCs must now be treated, and wet combustibles must also be treated. Volatilization, air stripping, and steam stripping could also remove the organics; an off-gas treatment system would be required, and the combustible residuals would still require immobilization. Supercritical fluid and solvent extraction could also be used; again, combustible residuals would remain.

Immobilization is probably the simplest method to treat the combustibles and filters. Polymer encapsulation is an efficient immobilization treatment which would fix the organic constituents. Cementation could be used on combustibles and filters. Shredding would be required with all immobilization techniques. A substantial waste volume increase penalty is paid if immobilization of unburned combustibles is done rather than residual ash.

6.13 Metal

6.13.1 Generation Process

This waste form is generated during non-fissile metal machining operations in which cutting oils and solvents are applied to the stock material. Cuttings or chips from the metals along with residues from the oils and solvents are mixed as they are caught beneath the machining equipment. The metal chips are drained and placed into 55 gallon drums with multiple linings for future disposition. They have been designated as a hazardous waste because the solvents used to clean or degrease the metal being machined are listed solvents under RCRA hazardous waste regulations.

The metal chips are generated in small quantities. As of August 1989, 0.7 m^3 or three drums of the waste had been accumulated, and these are being stored as mixed waste. The annual generation rate for this waste is about 0.2 m^3 or one drum.

6.13.2 Waste Characterization

The metal waste has not been sampled, but process knowledge allows a fairly complete characterization. The metal being machined typically consists of stainless steel, beryllium, or aluminum. The chips are contaminated with cutting oil and solvents. The cutting oil is not a hazardous material or waste, but the solvents used (1,1,1-trichloroethane and 1,1,2-trichloro-1,2,2-trifluoroethane) are subject to RCRA regulation once they have become a waste. The waste solvent and the other wastes with which it comes in contact are required to retain the Hazardous Waste Number designation of F001.

The metal waste is also considered low-level radioactive waste because of suspected plutonium contamination. As with chemical contaminants, no analytical data have been obtained to support this suspicion. Rather, this judgment is based on process knowledge. A sampling and analyses program will be required to fully characterize this waste.

6.13.3 Treatment Alternatives

Sixteen treatment options listed below were identified as candidates for this metal waste.

Thermal Treatments

Rotary Kiln Incinerator
Infrared Incinerator
Controlled Air Incineration
Plasma Arc Furnace
Metal Melter
Oxygen Enhanced Incineration

Chemical Treatments

Chemical Reduction-Oxidation

Physical Treatments

Aqueous Wash
Volatilization
Supercritical Fluid Extraction
Solvent Extraction
Air Stripping
Steam Stripping

Immobilization Treatments

Lime-Fly Ash Pozzolan
Portland Cement
Polymer Encapsulation

6.13.4 Treatment Evaluations

Incineration would destroy or volatilize organics for subsequent destruction or removal in an off-gas system; the latter would require an afterburner to destroy organics, possibly a scrubber to remove particulates, and a HEPA filter system prior to off-gas release to a building HEPA system. The plasma arc furnace and metal melter would both destroy or volatilize organics and provide a monolithic waste form.

Chemical reduction-oxidation could also be used to destroy organics, but would probably solubilize some of the material present and provide an aqueous stream for treatment.

Physical treatment methods such as aqueous wash, volatilization, supercritical fluid extraction, and air or steam stripping could be used to remove organics; in each case one or more secondary organic-bearing waste streams result.

The metal chips can be cemented once the organics have been removed. Polymer encapsulation might be able to immobilize both the organic and radioactive contaminants and meet LDR requirements.

6.14 Filters

6.14.1 Generation Process

Waste filters are generated at several locations within RFP. The filters of concern here are activated carbon, cartridge, and HEPA types used to filter liquid or air with suspected radiological and solvent contamination. The materials making up the filters can vary, although wood, fiberglass, plastic, rubber, and aluminum are commonly used in their construction. After generation, the waste is assayed for radioactive content and placed in 55 gallon drums. This waste is presently being generated at a rate of 0.6 m^3 per year.

Three drums of this waste (approximately 0.7 m^3) are presently stored at RFP. Two of the drums consist primarily of HEPA filters from glove box ventilation systems. In this case, the suspect hazardous constituents are solvents that were used in the glove box and subsequently absorbed in the filter. The third drum contains activated carbon filters that were used in a research and development project on removing solvents from water. These filters are also assumed to be contaminated with spent solvents.

6.14.2 Waste Characterization

The waste filters have not been sampled for radiological or hazardous constituents. The filters were used to filter fluid streams (air or liquid) that had come into contact with solvents (e.g., 1,1,1-trichloroethane and methylene chloride) and radioactive materials. The EPA Hazardous Waste Numbers applicable to this waste are F001 to F005 based on process knowledge.

6.14.3 Treatment Alternatives

Twenty treatment options have been identified as candidates for filters.

Thermal Treatments

Rotary Kiln Incinerator
Infrared Incinerator
Glass Melter
Controlled Air Incineration
Wet Air Oxidation
Cyclone Incinerator
Plasma Arc Incinerator
Fluidized Bed Incineration
Oxygen Enhanced Incineration

Chemical Treatments

Acid Digestion
Biodegradation

Physical Treatments

Aqueous Wash
Volatilization
Supercritical Fluid Extraction
Solvent Extraction
Air Stripping
Steam Stripping

Immobilization Treatments

Lime-Fly Ash Pozzolan
Portland Cement
Polymer Encapsulation

6.14.4 Treatment Evaluation

Although this is not a large waste category, some additional characterization should be done to enable more knowledgeable decisions to be made on the handling of this waste.

Incineration is a well developed method for destroying filters and hazardous organic materials. An advantage of incineration is a factor of ten reduction in volume. Shredding would be required in the case of fluidized bed incineration, but this disadvantage would be partially offset, at least, in that organics would be destroyed. Residual ash and off-gases from incineration would require further treatment.

Vitrification techniques would also require off-gas treatment, but the residuals would be encapsulated in glass. Wet air oxidation is another thermal treatment method that could be developed for filters.

Acid digestion and biodegradation could possibly be effective, but a considerable development effort would be required. Residuals would require immobilization.

Physical treatments could also be used. The filters could be washed with water to remove organic contaminants. The major drawback with this technique is that an aqueous waste contaminated with HOCs would then require treatment, and the wet filters would remain to be treated. Volatilization, air stripping, and steam stripping could also remove the organics; an off-gas treatment system would be required, and the filter residuals would still require immobilization. Supercritical fluid and solvent extraction could also be used; again, the combustible filters would require additional treatment.

Immobilization is probably the simplest method to treat the filters. Polymer encapsulation is an efficient immobilization treatment which would fix the organic constituents. Cementation could be used on filters once the organics have been removed. Shredding would help reduce the volume to be

immobilized.

6.15 Cemented Composite Chips

6.15.1 Generation Process

Metal fabrication activities within Building 444 at RFP include work on composite materials. These composite metals normally consist of stainless steel and depleted uranium. However, in some instances the uranium may be coupled with aluminum, beryllium, or even copper. During machining operations on these composite metals, oils and solvents are applied to the stock material. As described for the process generating metal chips (Section 6.6), cuttings or chips from the composite metal along with residues from the oils and solvents are all mixed as they are caught beneath the machining equipment. Instead of the drained composite chips being put directly into drums for future disposition as with metal chips, they are taken to Building 447 for cementation. The cementation is necessary because of the pyrophoric nature of the uranium. The cementation procedure involves layering chips and a cement/water mix into drums and using a vibrator to mix the contents. The drums are then stored in 4ft by 4ft by 7ft plywood boxes.

Cemented composite chips have been designated as a hazardous waste because the solvents used to clean or degrease the composite metal being machined are listed solvents under RCRA hazardous waste regulations. As a mixed, low-level waste, there are currently no off-site treatment, storage, or disposal facilities available to accept this waste. As of August 1989, 81 m^3 (21 full boxes and one half box) of the composite chip waste had been accumulated and future generation rates are expected to be near zero.

6.15.2 Waste Characterization

Characterization of the cemented composite chip waste depends primarily upon process knowledge. The composite metal being machined typically consists of depleted uranium and stainless steel, but the stainless steel is sometimes replaced with aluminum, beryllium, or copper. The chips, also consisting of these metals, are contaminated with cutting oil and solvents. The cutting oil is not a hazardous material or waste, but the solvents used (1,1,1-trichloroethane and 1,1,2-trichloro-1,2,2-trifluoroethane) are subject to RCRA regulation once they have become a waste. Because of the nature of the waste, leachability of metals may also be a concern.

The cemented composite chips were sampled once as part of the Waste Stream Identification and Characterization Program in 1986. The results of these analyses are given below.

6.15.2.1 Semivolatiles

Only one semivolatile compound was found. This was di-n-butyl phthalate with a concentration of 190 ppb.

6.15.2.2 Radiochemistry

The radiochemistry results for tritium were 0.11 ± 0.22 pCi/ml.

6.15.2.3 RCRA Characteristics

Ignitability - The single test showed a flash point greater than 60°C. This indicates that the waste is not ignitable.

EP Toxic Metals - None of the EP Toxic metals were observed at levels above the maximum concentrations set in 40 CFR 261.24. Three metals were, however,

observed at detectable levels. These were arsenic at 2 ppm, cadmium at <1 ppm, and lead at 2 ppm.

6.15.2.3 Applicable EPA Hazardous Waste Numbers

The hazardous waste numbers applicable to this waste are based solely on process knowledge. The analyses performed on the single sample did not identify any reasons to consider the waste hazardous, but analyses were not performed for volatiles which are the suspected cause of the hazardous designation. The solvents 1,1,1-trichloroethane and 1,1,2-trichloro-1,2,2-trifluoroethane are used in the process, and the wastes in which these solvents are contained are required to retain the Hazardous Waste Number of F001.

The cemented composite chip waste is also considered low-level radioactive waste primarily because of the presence of uranium in the composite material.

6.15.3 Treatment Alternatives

Sixteen treatment options have been identified as candidates for cemented composite chips.

Thermal Treatments

Rotary Kiln Incinerator
Infrared Incinerator
Controlled Air Incineration
Plasma Arc Furnace
Metal Melter
Oxygen Enhanced Incineration
Roasting

Physical Treatments
Aqueous Wash
Volatilization

Supercritical Fluid Extraction
Solvent Extraction
Air Stripping
Steam Stripping

Immobilization Treatments

Lime-Fly Ash Pozzolan
Portland Cement
Polymer Encapsulation

6.15.4 Treatment Evaluations

Waste characterization is needed before treatment of this waste form begins, both to determine hazardous constituents and waste form. It is probable that the waste does not exist as a monolithic form, given the manner of cement, water, and waste addition and mixing.

Pretreatment such as crushing would be required (whether monolithic or a mixture of particulates and agglomerates) before any of the cemented backlog could be treated. This may present a problem if done in air because of the pyrophoric nature of the uranium ships. All of the thermal techniques could be used to volatilize or destroy organics. The plasma arc furnace and metal melter could be used, if available because of use for other wastes, but would not be a first-choice treatment because of the presence of cement. Roasting could be used to eliminate organics and uranium pyrophoricity, converting uranium metal to oxide, but other metals could melt and form a slag in the roaster. In any case, the thermal processes would produce off-gases that would require treatment to destroy or adsorb remaining organics and remove particulates.

Physical treatments are also possible for organic removal from cemented composite chips Volatilization and air stripping would probably be easiest. Supercritical fluid or solvent extraction, with carbon dioxide or tetrahydrofuran, respectively, steam stripping, and aqueous washing might work but would

be more difficult. All of these methods would require treatment of the off-gas and/or extractant.

Once the organics are removed, the residuals can be immobilized by cementation. Again, polymer encapsulation of the size-reduced cemented waste should be evaluated to determine if organic encapsulation is sufficient to meet LDR requirements.

Virtually all of the above thermal and physical treatments can and should be used to process machining chips contaminated with listed organics before immobilization.

6.16 Acid

6.16.1 Generation Process

This acid waste stream is a combination of two waste streams from the chemical milling process in Building 444 at RFP. In this process beryllium parts are chemically milled in an acid bath followed by electropolishing with a second acid bath. The spent solutions from these acid baths are drained to a common tank and then to acid resistant containers outside the building.

Neutralization of these solutions using existing wastewater facilities has created a gel-like material which plugs the system. Pending development of an alternative treatment scheme, this waste has been accumulating in polyethylene drums for storage in cargo containers near Building 561. As of August 1989, 30 drums or 6.3 m^3 had been accumulated and yearly generation rates are estimated at less than 0.4 m^3.

6.16.2 Waste Characterization

Limited sampling has been performed on this waste stream. Much of the characterization can be based on the makeup chemicals to the process and the manner in which the materials were used. The chemical milling acid bath contains a mixture of 75% phosphoric acid, 3% sulfuric acid, and chromium trioxide. The electropolishing solution also contains phosphoric acid.

The solutions were sampled and analysed as follows:

Parameters Analyzed	Milling Solution	Electropolish Solution
RCRA Characteristics		
Corrosivity	X	X
Reactivity		X
EP Toxic Metals	X	X
Radiochemistry	X	X

The analytical results are discussed in the following paragraphs.

6.16.2.1 RCRA Characteristics

Corrosivity - Both solutions qualify as RCRA corrosive with pH values less than 2.0.

Reactivity - These solutions qualify as reactive because of the 2,800 ppm reactive cyanide content. The combination of low pH and cyanide presents a very hazardous condition. In addition, hydrogen cyanide gas generation has probably occurred in the storage containers. Extreme caution should be used in dealing with this waste.

EP Toxic Metals - Analytical results for EP Toxic metals in this waste are summarized as follows:

Metal	Concentration, ppm Acid Bath	Electropolishing

Arsenic	-	153
Cadmium	7	2
Chromium	92,700	85
Lead	72	406
Selenium	-	<1
Silver	17	-

6.16.2.2 Radiochemistry

The results of the radiochemistry analyses are as follows:

	Concentration,* pCi/L	
Analysis	Acid Bath	Electropolishing
Am-241	-	3.3 ± 2.5
U-233,234	14 ± 18	-
U-238	51 ± 43	-
Tritium	-	110 ± 200

* The plus or minus (±) values indicate the 95% confidence range for the reported values.

6.16.3 Treatment Alternatives

Ten treatment options listed below were identified for acid:

Thermal Treatments

Glass Melter
Microwave Melter
Plasma Arc Furnace

Chemical Treatments

Neutralization
Precipitation

Immobilization Treatments

Lime-Fly Ash Pozzolan
Portland Cement
Polymer Encapsulation

6.16.4 Treatment Evaluation

Additional waste characterization is needed to determine cyanide and Cr(VI) concentrations. Additional analysis for EP Toxic metals would also be beneficial.

Neutralization, oxidation of the cyanide (if present), and reduction of Cr(VI) should be done prior to any treatment. Following this pretreatment, the most logical short term solution would be precipitation with immobilization of the resulting sludge. Additional treatment of the filtrate such as evaporation and subsequent salt immobilization, may be necessary to meet disposal requirements. With some development this waste stream could be treated in the existing RFP waste treatment facility.

Development should continue on thermal treatments for long term application, especially those that yield a vitrified product, since these treatments tend to minimize product streams requiring further treatment. Neutralization and precipitation might still be used as a pretreatment step, with vitrification of the sludge and, perhaps, salt produced by evaporation of the phosphate solution remaining from precipitation. Off-gas treatment would be necessary for thermal treatments.

6.17 PCB Solids

6.17.1 Generation Process

The polychlorinated biphenyl (PCB) waste discussed in this section is in solid form. Although all of this waste is considered to be radiologically contaminated, not all of it meets the definition for low-level mixed waste. PCBs are regulated under the Toxic Substances Control Act (TSCA) rather than under RCRA; therefore, by definition, PCBs cannot be RCRA hazardous wastes. Much of the PCB waste accumulated at RFP is contaminated with RCRA hazardous constituents and meets the definition of mixed waste. This waste is regulated under the AEA, RCRA, and TSCA.

PCB solid waste refers to items such as contaminated equipment and cleanup materials that were generated during removal of PCB transformers. The waste was generated at various locations throughout the plant. During removal operations, waste was drummed for storage with no pretreatment. In some instances, items were cleaned or wiped off using solvents to dissolve the transformer oil. Rags or Kimwipes so generated were also put into the drums. Drums containing these cleanup materials are also designated as RCRA hazardous because the solvents used were trichloroethylene and later, 1,1,1-trichloroethane: both of these are considered listed waste when they are used for the purpose of cleaning or degreasing.

PCB solid waste is no longer being generated since the project to replace PCB containing transformers is now complete. Eighty four drums (17 m^3) of this waste was generated and is currently being stored. Much of this PCB waste inventory is RCRA hazardous as well as PCB and radiologically contaminated.

6.17.2 Waste Characterization

The PCB waste has not been sampled. Characterization is based on knowledge of the generation process and on the materials going into the waste. The PCB-contaminated equipment was identified as such while still in use, prior to the activities in which the waste was generated. It was then clear that PCB contamination would be a factor in any of the wastes generated from the removal of this equipment. RCRA concerns were also involved whenever solvents were used to clean PCB oils from equipment or other items. Based on process knowledge, the only two solvents used for this purpose were trichloroethylene and 1,1,1-trichloroethane. Both of these solvents generate wastes identified by EPA Hazardous Waste Numbers F001 and F002.

6.17.3 Treatment Alternatives

Fourteen treatment options were identified as candidates for PCB contaminated solids.

Thermal Treatments

Rotary Kiln Incinerator
Infrared Incinerator
Glass Melter
Controlled Air Incineration
Plasma Arc Furnace
Fluidized Bed Incineration
Oxygen Enhanced Incineration

Chemical Treatments

Catalytic Dehalogenation
Biodegradation

Physical Treatments

Volatilization
Supercritical Fluid Extraction

Immobilization Treatments

Lime-Fly Ash Pozzolan
Portland Cement
Polymer Encapsulation

6.17.4 Treatment Evaluation

The PCB solids require complete characterization before treatment. While the PCB and radiologic compounds of the waste drums are characterized, the levels of 1,1,1-trichloride and trichloroethylene are unknown. A full characterization of each barrel will allow an assessment of which RCRA, TSCA, and AEA rules apply. The interaction of RCRA, TSCA, and AEA rules may indicate that several treatment processes are best for PCB solids. For example, the treatment required for barrels that only have LLW and TSCA wastes may differ from the treatment required for barrels that contain all three waste types.

For much of the waste the PCB content will dictate the treatment. The TSCA regulations dictate that any PCB wastes greater than 500 ppm require incineration. For PCB content greater than 50 ppm but less than 500 ppm, the regulations allow other treatment options. For example, immobilization might provide adequate treatment for wastes with small amounts of PCBs and hazardous constituents. However, at this time incineration is the only option which meets all legal requirements for all PCB wastes.

Physical and chemical forms of pretreatment could provide some benefit. Extracting the radioactive and the hazardous components from the PCB waste stream would allow offsite incineration of the PCBs. Or perhaps removing the PCBs with an extraction process would prove more feasible. Either option would assume that DOE establishes a lower limit for determining what is, and what is not, a low level waste.

Any treatment scenario for PCB solid wastes will require multiple process steps. The wastes from PCB incineration might require additional treatments to remove hazardous constituents or to immobilize the low level radioactive components. Similarly, any off-gases from PCB incineration would require processing, such as scrubbing and multiple-HEPA filtering techniques.

6.18 PCB Liquids

6.18.1 Generation Process

The polychlorinated biphenyl (PCB) waste discussed in this section is in the form of liquids. Capacitors are also included since they can contain liquid. All of this waste is considered to be radiologically contaminated, but not all of the waste meets the definition for low-level mixed waste. PCBs are regulated under the Toxic Substances Control Act (TSCA) rather than under RCRA; therefore, by definition, PCBs cannot be RCRA hazardous wastes. Much of the PCB waste accumulated at RFP is contaminated with RCRA hazardous constituents and meets the definition of mixed waste. This waste is regulated

under the AEA, RCRA, and TSCA.

PCB liquid waste is generated during the removal of PCB contaminated electrical or hydraulic equipment. The liquid may vary from high percentage PCB transformer oil to hydraulic fluids contaminated with comparably low concentrations of PCB. This waste was packaged in drums for storage, and, in some cases, the containers were designated as RCRA hazardous because of the use of trichloroethylene and 1,1,1-trichloroethane for cleaning or rinsing hardware items. The inventory for this waste is 25 drums (5.2 m^3).

Radiologically-contaminated PCB capacitors are also being accumulated and stored in drums for future treatment or disposal. The capacitors, which are generally sealed units, are of various sizes and individually contain between 0.25 and 4.2 gallons of liquid. Continued generation of this waste is not anticipated. Currently, the inventory of drums is 32 (6.7 m^3). Unlike the other categories of PCB waste, the capacitors are not suspected of being contaminated with any RCRA hazardous constituents.

6.18.2 Waste Characterization

The PCB liquid waste has not been sampled. Characterization is based on knowledge of the generation process and on the materials going into the waste. The PCB-contaminated liquids, hydraulic fluids, and capacitors were identified as such while they were still in use, prior to the activities in which the waste was generated. It was then clear that PCB contamination would be a factor in any of the wastes generated from the removal of these items. RCRA concerns were also involved whenever solvents were used to clean PCB oils from equipment or other items. Based on process knowledge, the only two solvents used for this purpose were trichloroethylene and 1,1,1-trichloroethane. Both of these solvents generate wastes identified by EPA Hazardous Waste Numbers F001 and F002.

6.18.3 Treatment Alternatives

Twelve treatment options have been identified as candidates for PCB liquids.

Thermal Treatments

Rotary Kiln Incinerator
Infrared Incinerator
Glass Melter
Controlled Air Incineration
Cyclone Incinerator
Liquid Injection Incinerator
Plasma Arc Furnace
Fluidized Bed Incineration
Oxygen Enhanced Incineration

Chemical Treatments

Catalytic Dehalogenation
Biodegradation

Physical Treatments

Filtration

Immobilization Treatments

Organic Solidification

6.18.4 Treatment Evaluation

A thorough characterization of these PCB wastes should be completed before the waste processing proceeds. Many analyses of the liquid wastes have already been made for PCBs and radioactive content, but the full characterization of the drums containing the liquids and capacitors is not complete. For example, analyses for chlorinated solvents have not been made.

PCB regulations either require thermal destruction or identify it as one of the allowable alternatives, depending on the concentration of PCBs and on the form of the waste. Incineration is required for disposal of liquids

containing greater than 500 ppm of PCBs and for large capacitors containing PCBs.

Physical and chemical forms of separation and processing could be used to reduce PCB and halogenated hydrocarbon content in wastes or to separate the waste into a hazardous waste stream and a radioactive waste stream. If the waste could be separated into two streams so that each of the waste streams were no longer mixed waste, the licensing could be simpler. A lower limit for radioactive content (below which a given stream could be sent to standard commercial treatment facilities) would need to be defined and agreed upon before separation would be beneficial.

Most treatment schemes for these wastes would require multiple process steps. If chemical methods were used to reduce the halogenated organic solvent and/or PCB content, the resulting fluids would still have to be immobilized before land disposal. And incineration processes producing an ash would also require immobilization of the ash. Off-gases from incinerators and other operations would require some processing, such as scrubbing and multiple stages of HEPA filtration. Incinerators at several DOE sites have been found capable of destroying PCBs in EPA-monitored test burns, including the Rocky Flats fluid bed incinerator (1). Several commerical incinerators have been licensed to process PCB liquid wastes which are not radioactively contaminated.

6.18.5 Reference

(1) A. J. Johnson, et al., Incineration of Polychlorinated Biphenyl Using a Fluidized Bed Incinerator, RFP 3271, Rockwell International, Golden, CO, September 1981.

6.19 Summary of Individual Waste Stream Treatments

An extensive list of treatment alternatives was considered when evaluating possible treatments for each of the eighteen waste streams considered in this section. These alternatives were divided into five groups - thermal, chemical, physical, immobilization, and high level waste solidification. None of the high level waste solidification alternatives were selected for use on the waste streams because other, simpler techniques were sufficient.

Possible treatment alternatives that were selected for each stream are summarized in Table 6.1, Thermal Treatment; Table 6.2, Chemical Treatments; Table 6.3, Physical Treatments; and Table 6.4, Immobilization Treatments. As mentioned previously, an attempt was made to include any technology that theoretically might work. Many of the technologies would be impractical, if not impossible, to actually implement. Technology ranking will be done in Treatment Plan No. 1.

FIGURE 6.1: THERMAL TREATMENT ALTERNATIVES SUMMARY

	ROCKY FLATS WASTES																		
	6.1 SOL BYPASS SLUDGE	6.2 SOIL & CLEANUP DEBRIS	6.3 CUTOFF SLUDGE	6.4 SOLIDIFIED ORGANIC/TRU	6.5 COMBUSTIBLES & FILTERS/TRU	6.6 METAL/TRU	6.7 AQUEOUS SLUDGE/TRU	6.8 MISC. WASTES/TRU	6.9 PART./SLUDGE WASTES/TRU	6.10 ROASTER OXIDE	6.11 PBI OIL	6.12 COMBUSTIBLES	6.13 METAL	6.14 FILTERS	6.15 CEMENTED COMPOSITE CHIPS	6.16 ACID	6.17 PCB SOLIDS	6.18 PCB LIQUID
5.1.1.1 ROTARY KILN INCINERATOR		X	X	X	X	X		X	X	X	X	X	X	X	X		X	X	
5.1.1.2 INFRARED INCINERATOR		X	X	X	X	X		X	X	X	X	X	X	X	X		X	X	
5.1.1.3 ADVANCED ELECTRIC REACTOR		X						X			X								
5.1.1.4 MOLTEN SALTS																			
5.1.1.5 GLASS MELTER	X	X	X	X	X		X	X	X		X	X		X		X	X	X	
5.1.1.6 MICROWAVE MELTER	X	X	X				X	X		X						X			
5.1.1.7 CONTROLLED AIR INCINERATION		X	X	X	X	X		X	X	X	X	X	X	X	X		X	X	
5.1.1.8 WET AIR OXIDATION					X						X	X		X					
5.1.1.9 CYCLONE INCINERATOR					X				X		X	X		X				X	
5.1.1.10 BELGIUM INCINERATION PROCESS																			
5.1.1.11 LIQUID INJECTION INCINERATION											X							X	
5.1.1.12 PLASMA ARC FURNACE	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
5.1.1.13 FLUIDIZED BED INCINERATION					X				X		X	X		X			X	X	
5.1.1.14 IN SITU VITRIFICATION																			
5.1.1.15 METAL MELTER						X							X		X				
5.1.1.16 OXYGEN-ENHANCED INCINERATION		X	X	X	X	X		X	X	X	X	X	X	X	X		X	X	
5.1.1.17 ROASTING															X				

RF-WST-K

FIGURE 6.2: CHEMICAL TREATMENT ALTERNATIVES SUMMARY

	ROCKY FLATS WASTES																		
	6.1 SOL BYPASS SLUDGE	6.2 SOIL & CLEANUP DEBRIS	6.3 CUTOFF SLUDGE	6.4 SOLIDIFIED ORGANIC/TRU	6.5 COMBUSTIBLES & FILTERS/TRU	6.6 METAL/TRU	6.7 AQUEOUS SLUDGE/TRU	6.8 MISC. WASTES/TRU	6.9 PART./SLUDGE WASTES/TRU	6.10 ROASTER OXIDE	6.11 FBI OIL	6.12 COMBUSTIBLES	6.13 METAL	6.14 FILTERS	6.15 CEMENTED COMPOSITE CHIPS	6.16 ACID	6.17 PCB SOLIDS	6.18 PCB LIQUID	
5.2.1.1 AQUEOUS PHSE ALKL DESTRUCTION																			
5.2.1.2 CATALYTIC DEHALOGENATION		X														X	X		
5.2.1.3 ULTRAVIOLET LIGHT/OXIDATION																			
(ELECTRODECONTAMINATION) 5.2.1.4 ELECTROCHEM REM OF MTL CONTAM						X													
5.2.1.5 ACID DIGESTION					X			X	X		X	X		X					
5.2.1.6 BIODEGRADATION		X		X	X			X			X	X		X			X	X	
5.2.1.7 NEUTRALIZATION															X				
5.2.1.8 PRECIPITATION															X				
5.2.1.9 CHEMICAL REDUCTION-OXIDATION						X					X		X						
5.2.1.10 ACID LEACHING						X													

RF-WST-L

FIGURE 6.3: PHYSICAL TREATMENT ALTERNATIVES SUMMARY

	ROCKY FLATS WASTES																		
	6.1 SOL. BYPASS SLUDGE	6.2 SOIL & CLEANUP DEBRIS	6.3 CUTOFF SLUDGE	6.4 SOLIDIFIED ORGANIC/TRU	6.5 COMBUSTIBLES & FILTERS/TRU	6.6 METAL/TRU	6.7 AQUEOUS SLUDGE/TRU	6.8 MISC. WASTES/TRU	6.9 PART./SLUDGE WASTES/TRU	6.10 ROASTER OXIDE	6.11 FBI OIL	6.12 COMBUSTIBLES	6.13 METAL	6.14 FILTERS	6.15 CEMENTED COMPOSITE CHIPS	6.16 ACID	6.17 PCB SOLIDS	6.18 PCB LIQUID
5.3.1.1 AQUEOUS WASH					X	X				X		X	X	X	X				
5.3.1.2 VOLATILIZATION		X		X	X	X		X		X	X	X	X	X	X		X		
5.3.1.3 FILTRATION											X							X	
5.3.1.4 CRYSTALLIZATION																			
5.3.1.5 SUPERCRITICAL FLUID EXTRACTION		X			X	X		X		X		X	X	X	X		X		
5.3.1.6 ION EXCHANGE																			
5.3.1.7 REVERSE OSMOSIS																			
5.3.1.8 SOLVENT EXTRACTION		X	X	X	X					X		X	X	X	X				
5.3.1.9 DISTILLATION											X								
5.3.1.10 AIR STRIPPING		X		X	X	X		X		X	X	X	X	X	X				
5.3.1.11 ACTIVATED CARBON ADSORPTION																			
5.3.1.12 STEAM STRIPPING		X		X	X	X		X		X		X	X	X	X				
5.3.1.13 COMMINUTION AND BENEFICIATION																			
5.3.1.14 CENTRIFUGATION											X								

RF-WST-M

FIGURE 6.4: IMMOBILIZATION ALTERNATIVES SUMMARY

	ROCKY FLATS WASTES																		
	6.1 SOL. BYPASS SLUDGE	6.2 SOIL & CLEANUP DEBRIS	6.3 CUTOFF SLUDGE	6.4 SOLIDIFIED ORGANIC/TRU	6.5 COMBUSTIBLES & FILTERS/TRU	6.6 METAL/TRU	6.7 AQUEOUS SLUDGE/TRU	6.8 MISC. WASTES/TRU	6.9 PART./SLUDGE WASTES/TRU	6.10 ROASTER OXIDE	6.11 PBI OIL	6.12 COMBUSTIBLES	6.13 METAL	6.14 FILTERS	6.15 CEMENTED COMPOSITE CHIPS	6.16 ACID	6.17 PCB SOLIDS	6.18 PCB LIQUID	
5.4.1.1 BITUMEN SOLIDIFICATION PROCESS																			
5.4.1.2 SORPTION																			
5.4.1.3 LIME-FLY ASH POZZOLAN	X	X	X		X	X	X	X	X	X		X	X	X	X	X	X		
5.4.1.4 PORTLAND CEMENT	X	X	X		X	X	X	X	X	X		X	X	X	X	X	X		
5.4.1.5 POLYMER ENCAPSULATION	X	X	X		X	X	X	X	X	X		X	X	X	X	X	X		
5.4.1.6 ORGANIC SOLIDIFICATION											X								

RF-WST-N

7.0 DEPARTMENT OF ENERGY TREATMENT TECHNOLOGIES

7.1 Introduction

This section discusses treatment technologies and associated treatment units for radioactive mixed waste (RMW) processing, both in existence and under development at DOE facilities. The DOE is pursuing a variety of treatment technologies for its RMW in an effort to decrease the toxicity of these wastes and reduce the migration potential of hazardous and radioactive constituents under subsequent disposal conditions. Where possible, DOE is adapting commercially available technology and incorporating the necessary design features for radioactive waste processing; e.g., shielding, radionuclide containment, and criticality control. DOE additionally promotes the development of promising new treatment technologies for application to hazardous and mixed wastes resulting from defense-related activities.

Many of the treatment technologies in use and under development in the DOE defense complex are appropriate for RFP waste streams, and have a reasonable potential of achieving the RCRA LDR treatment standards for hazardous constituents in these wastes. The technologies and associated treatment units are divided into several process categories: thermal; chemical; physical; and immobilization treatment methods. These processes are utilized primarily to treat DOE's low-level and transuranic RMW. A fifth category includes the highly specialized vitrification facilities which DOE will use to immobilize HLW sludges generated from fuel and target reprocessing operations. Figure 7.0 lists the treatment technologies in use and planned at DOE facilities. This figure also serves as a key to the processes used by DOE treatment units as shown in Figures 7.1 through 7.4.

The DOE sponsors aggressive research, development and demonstration (RD&D) efforts for alternate hazardous and mixed waste treatment technologies through the Hazardous Waste Remedial Actions Program in Oak Ridge, Tennessee. A discussion of current RD&D projects at DOE laboratories appears in a separate section that follows.

FIGURE 7.0: DESCRIPTIONS OF TECHNOLOGIES FOR ENERGY DEPARTMENT WASTE FACILITIES

Reference Number	Description
1.	Solidification, unspecified (5.4.1)
2.	Solidification with Portland Cement (5.4.1.4)
3.	Solidification with Portland Cement and Fly Ash (5.4.1.4)
4.	Solidification with Portland Cement, Fly Ash and Clay (5.4.1.4)
5.	Solidification with Portland Cement, Fly Ash and Slag (5.4.1.4)
6.	In Drum Solidification (5.4.1.4, 5.4.1.6)
7.	In Drum Solidification with Portland Cement (5.4.1.4)
8.	In Drum Solidification with Portland Cement and Clay (5.4.1.4)
9.	In Drum Solidification with Portland Cement and Diatomaceous Earth (5.4.1.4)
10.	In Drum Solidification with Portland Cement and Fly Ash (5.4.1.4)
11.	In Drum Solidification with Portland Cement and RAMCOTE™ (5.4.1.4)
12.	In Drum Solidification with Portland Cement, Clay and Fly Ash (5.4.1.4)
13.	In Drum Solidification with Portland Cement, Clay and Slag (5.4.1.4)
14.	In Drum Solidification with Environstone™ (5.4.1.6)
15.	Carbon Adsorption, Reverse Osmosis, Ion Exchange, and Evaporation (5.3.1.11, 5.3.1.7, 5.3.1.6, 5.3.1.2)
16.	Sort, Compact, Shred and Grout (5.3.1.13, 5.4.1.4)
17.	Sort, Shred and Grout (5.3.1.13, 5.4.1.4)
18.	Distillation (5.3.1.9)
19.	Incineration, unspecified (5.1.1)
20.	Stationary Grate Incineration (5.1.1)
21.	Controlled Air Incineration (5.1.1.7)
22.	Cyclone Incineration (5.1.1.9)
23.	Fluidized Bed Incineration (5.1.1.3)
24.	Glass Melting Incineration (5.1.1.5)
25.	Roasting (5.1.1.17)
26.	Rotary Kiln Incineration (5.1.1.1)
27.	Calcination (5.3.1.2)
28.	Glass-Ceramic Process (5.5.1.1)
29.	Vitrification (5.1.1.5)
30.	Microwave Melting (5.1.1.6)
31.	Evaporation (5.3.1.2, 5.2.1.7, 5.3.1.3, 5.3.1.11, 5.3.1.7, 5.3.1.6)
32.	Acid Leaching (5.2.1.10)
33.	Plasma Arc Incineration (5.1.1.12)

7.2 Existing and Planned Treatment Units

This section will discuss existing and planned thermal, chemical, physical, and immobilization units for RMW within DOE.

7.2.1 Existing and Planned Thermal Treatment Units

Several varieties of thermal treatment units are operating or planned for operation at DOE facilities, with treatment capacity phased in over the next five to six years. These include controlled air, rotary kiln, fluidized bed, and stationary grate incinerators; glass melters; microwave melting systems; and pyrophoric metal "roasters". Selected information on these thermal treatment units is shown in Figure 7.1.

At present, the Waste Experimental Production Facility (WERF) at INEL is the only DOE incinerator capable of processing low-level RMW. The controlled air incinerator at LLNL is restricted to scintillation cocktails and other wastes generated from biomedical research. No chlorinated compounds can be introduced into this facility.

DOE has no thermal treatment capacity currently available for transuranic RMW. Given the present planning base, the earliest available facility would be the Controlled Air Incinerator at the LANL. This facility is scheduled to be operational by mid to late 1990, depending on the time necessary for the State of New Mexico to promulgate operations and emissions regulations for waste incineration. There is currently a moratorium on solid waste incineration in the State of New Mexico.

A glass melter, capable of processing low-level RMW, is located at Mound and is scheduled for operation in 1990. Another pilot-scale melter is proposed for installation and testing at the RFP; this development program is discussed in Section 7.4. The RFP Glass Melter will be designed to process both low-level and transuranic RMW.

FACILITY	TREATMENT UNIT NAME	UNIT TYPE	START DATE	TREAT. CAP.	UNIT OF MEASURE	TREATMENT CAPABILITY RCRA	TSCA	HLW	TRU	LLW	COMMENTS
PRODUCTION UNITS:											
LANL	TA-50 TDF	21	1990	45	Kg/hr	IS	PCB		X	X	
LANL	TA-50 TDF	21	1995	180	Kg/hr	X	X			X	
LANL	TA-50 MICROWAVE MELTER	30	1994	NA	NA	X			X	X	PROPOSED UNIT
MOUND	GLASS MELTER	24	1990	23	Kg/hr	IS				X	
PANTEX	HAZ. WASTE TRT. & PROC.	21	1995	200	M^3/Y	X				X	PROPOSED UNIT
RFP	FLUIDIZED BED INCIN.	23	--	75	Kg/hr	IS			X	X	ON HOLD
RFP	STATIONARY GRATE	20	1957	15	Kg/hr				X		SHUTDOWN FEB,1990
RFP	371 INCINERATOR	26	NA	40	Kg/hr				X		NO LONGER OPERATING
INEL	WERF	21	OPER	454	Kg/hr	IS				X	
INEL	PREPP	35,26	1992	909	Kg/hr	IS			X	X	TSCA PERMIT POSSIBLE
INEL	PLASMA ARC	33	1995	454	Kg/hr	X			X	X	PROPOSED UNIT
SRS	CIF	26	1992	28,863	Kg/hr	X				X	
LLNL	CA INCINERATOR	21	OPER	60	Kg/hr	IS				X	BIOMEDICAL WASTE; NO HALOGENATED COMPOUNDS
LLNL	DWTF	26,36	1996	45	Kg/hr	X				X	
ORGDP	TSCA INCINERATOR	26	1990	450	Kg/hr	X	PCB			X	
HANFORD	303-M OXIDE	25	OPER	91	Kg/hr	IS				X	PYROPHORIC METALS ONLY
EXPERIMENTAL UNITS:											
SRS	BETA-GAMMA INCIN.	21	1984	180	Kg/hr					X	NO PLANS FOR RESTART
MOUND	CYCLONE INCIN	22	1975	2	Drums/day					X	SCHED. FOR REMOVAL-1990
RFP	MICROWAVE MELTER	30	1990	20	Kg/hr	X			X	X	DEMONSTRATION UNIT
RFP	FB PILOT PLANT	23	1974	9	Kg/hr	X	PCB		X	X	INACTIVE
RFP	GLASS MELTER	24	1990	60	Kg/hr	X			X	X	PILOT-SCALE
SRS	PWI	21	1985	10	Kg/hr				X		

M9-GT-0060-02

20 - stationary-grate incineration (5.1.1)
21 - controlled-air incineration (5.1.1.7)
22 - cyclone incineration (5.1.1.9)
23 - fluidized-bed incineration (5.1.1.3)
24 - glass-melting incineration (5.1.1.5)
25 - roasting (5.1.1.17)
26 - rotary-kiln incineration (5.1.1.1)
30 - microwave melting (5.1.1.6)
33 - plasma-arc incineration (5.1.1.12)
35 - shred and grout
36 - evaporation and grout

NOTE:
NA - NOT AVAILABLE
IS - INTERIM STATUS
PCB - POLYCHLORINATED BIPHENYL

Figure 7.1 - Existing and Planned Thermal Treatment Units at DOE Facilities

Developmental work with microwave melting systems has been conducted at LANL and the RFP; the RFP program is discussed in Section 7.4. LANL is in the early planning stages of a production-scale unit which is estimated to be available in 1994.

A plasma arc furnace is proposed for installation at the INEL and may be available in the 1993-1994 timeframe.

7.2.2 Existing and Planned Physical and Chemical Treatment Units

Prior capacity surveys show relatively few physical and chemical processes in use or planned for RMW treatment at DOE facilities. Those identified are typically used for treatment of wastewaters and supernatant. The rated capacity and capability of these treatment units are shown in Figure 7.2.

Within the DOE waste management complex, evaporative processes are used as a volume reduction technique for aqueous waste streams. The largest evaporators are located at sites that generate HLW from reactor fuel and target reprocessing operations. The New Waste Calcining Facility (NWCF), located at the (INEL), uses a fluidized bed calcination process to convert liquid HLW to a granular solid. The calcine product is then pumped to an underground tank for storage.

At the Hanford Reservation, radioactively-contaminated hexone (methyl isobutyl ketone) is presently stored in two below-grade tanks. A distillation unit is planned to effect the separation of radioactive and organic materials. The distillate will be stored for subsequent treatment in a mobile incinerator. The distillation bottoms will be processed for disposal at the Waste Isolation Pilot Plant.

A nitric acid process is used to leach contaminants from HEPA filters at the Idaho Chemical Processing Plant at INEL. The nitric acid solution, containing the radioactive and hazardous elements, is then processed in the

FACILITY	TREATMENT UNIT NAME	UNIT TYPE	START DATE	TREAT. CAP.	UNIT OF MEASURE	TREATMENT CAPABILITY RCRA	TSCA HLW	TRU LLW	COMMENTS
PHYSICAL TREATMENT UNITS:									
INEL	NWCF	27	OPER	3,346	M^3/YR	IS	X		DEDICATED FOR HLW PRC.
INEL	ICPP EVAPORATOR	31	OPER	15,423	M^3/YR	IS		X	
INEL	EVAPORATOR	31	TBD	185,000	M^3/YR			X	UNDER EVALUATION
SRS	ETF	15	OPER	396,900	M^3/YR	X		X	F/H WASTEWATER TREAT.
HANFORD	HEXONE TANKS	18, 19	1991	210	gal/hr	X		X X	CAPACITY FOR MOBILE INCINERATOR ONLY
CHEMICAL TREATMENT UNITS:									
INEL	HEPA FILTER LEACH TANK	32	1990	161	M^3/YR	IS	X		

Figure 7.2 - Physical and Chemical Treatment Units in Operation and Planned at DOE Facilities

FACILITY	TREATMENT UNIT NAME	UNIT TYPE	START DATE	TREAT. CAP.	UNIT OF MEASURE	TREATMENT CAPABILITY RCRA	TSCA HLW	TRU LLW	COMMENTS
HIGH-LEVEL WASTE IMMOBILIZATION FACILITIES									
WVDP	VITRIFICATION SYSTEM	29	1993	62	M^3/YR	X	X		
SRS	DWPF	29	1992	4,150	M^3/YR	X	X		Hg RECOVERY
INEL	WASTE IMMOBILIZATION FAC.	28	2012	1,300	M^3/YR	X	X		GLASS-CERAMIC PROCESS
HANFORD	HWVP	29	1999	3,785	M^3/YR	X	X		

M9-GT-0060-03

Figure 7.3 - Planned DOE High-Level Waste Immobilization Facilities

NOTE: NA - NOT AVAILABLE
IS - INTERIM STATUS

15 - carbon adsorption, reverse osmosis, ion exchange and evaporation (5.3.1.11, 5.3.1.7, 5.3.1.6, 5.3.1.2)
18 - distillation (5.3.1.9)
19 - incineration, unspecified (5.1.1)
27 - calcination, (5.3.1.2)
28 - glass-ceramic process (5.5.1.1)
29 - vitrification (5.1.1.5)
31 - evaporation (5.3.1.2, 5.2.1.7, 5.3.1.3, 5.3.1.11, 5.3.1.7, 5.3.1.6)
32 - acid leaching (5.2.1.10)

calcining facility. The HEPA Filter Leach Tank is currently being tested and should be operational by mid-1990.

7.2.3 Existing and Planned High Level Waste Immobilization Units

7.2.3.1 Background

HLW, generated from the reprocessing of spent nuclear fuel and irradiated reactor targets, generally contains more than 99% of the nonvolatile fission products produced in the fuel or targets during reactor operation. HLW is a special category of RMW and is considered to be a RCRA hazardous waste by its characteristics (corrosivity and EP Toxic metals). HLW is typically generated as an acidic liquid which undergoes one or more treatment steps prior to storage; e.g., neutralization, precipitation, decantation, and evaporation.

Most of the U.S. inventory of HLW is the result of DOE's defense activities and is currently stored at the Savannah River Site (SRS), INEL, and the Hanford Reservation. A small amount of commercial HLW was generated at the Western New York Nuclear Service Center (WNYNSC), near West Valley, New York. The DOE received custody of the WNYNSC via the West Valley Demonstration Project (WVDP) Act in 1980.

In the mid-1970's the DOE recognized the significant cost and safety advantages associated with immobilizing HLW in a stable, solid form. Several alternative waste forms for the SRS waste were evaluated in terms of product quality and reliability of fabrication. The evaluation led to a decision to use a vitrification technique at the Defense Waste Processing Facility to convert the easily dispersed waste into borosilicate glass. This process was subsequently chosen for use at the WVDP and the Hanford Waste Vitrification Plant (HWVP). A glass-ceramic process is currently under evaluation for immobilizing HLW at the INEL.

7.2.3.2 High-Level Waste Immobilization Facilities

Four DOE HLW immobilization facilities are in various stages of planning, design and construction (see Figure 7.3). The Defense Waste Processing Facility (DWPF) at the SRS will be the first of these to operate; construction is 99% complete and hot startup is scheduled for 1992. The WVDP vitrification system is scheduled to operate in 1993. The HWVP at Hanford is in preliminary design. Once processed, all HLW will be stored onsite until a federal geologic repository becomes available.

7.2.4 Existing and Planned Immobilization Units - LLW/TRU

Immobilization systems are widely used in DOE facilities; ten sites are currently operating or plan to operate units for stabilizing low-level and transuranic waste. Many of these units have obtained RCRA Interim Status and are capable of treating RMW while others are used exclusively for radioactive waste processing. Selected information on DOE's waste immobilization units appears in Figure 7.4.

The largest immobilization units at DOE sites were designed for treating the large volumes of liquid low-level waste that will be generated from HLW pretreatment. Examples include the Hanford Grout Treatment Facility and the Z-Area Saltstone Facility at SRS. Numerous other smaller units are in use including a number of "in-drum" mixing systems. The DOE immobilization units typically use cement- or grout-based formulations with a variety of other additives such as fly ash, slag, clay, and diatomaceous earth. Some sites are using commercial proprietary mixtures.

7.3 Waste Research, Development, and Demonstration (RD&D) Facilities

The development and demonstration of alternate technologies for treatment and disposal of DOE hazardous and radioactive mixed wastes are conducted through two programs in DOE: The Hazardous Chemical Waste Research

	TREATMENT UNIT NAME	UNIT TYPE	START DATE	TREAT. CAP.	UNIT OF MEASURE	TREATMENT CAPABILITY RCRA	TSCA	HLW	TRU	LLW	COMMENTS
LANL	TA-50 VAC. FILTER OP.	9	OPER	255	M^3/YR				X	X	NO RCRA PERMIT
LANL	TA-55 Pu FACILITY	14	OPER	15	M^3/YR				X		NEWLY GEN. WASTE ONLY
LANL	PRETREATMENT PLANT	7	OPER	2	M^3/YR				X		NON-RCRA WASTE
LANL	WPF TA-54 (W)	17	1993	180	M^3/YR				X		STORED WASTE ONLY
MOUND	ALPHA CONT. H_2O PROC. FAC.	34	OPER	11,809	M^3/YR				X	X	NO RCRA PERMIT
MOUND	H-3 WTR. SOLID FAC.	8	OPER	114	M^3/YR					X	NO RCRA PERMIT
RFP	778 PONDCRETE	2	OPER	1,700	M^3/YR	IS				X	
RFP	374 SALTCRETE	2	OPER	680	M^3/YR	IS				X	
RFP	774 VAC. FILTER OP.	9	OPER	120	M^3/YR	IS			X		
RFP	374 VAC. FILTER OP.	9	OPER	280	M^3/YR	IS			X	X	
RFP	774 SPEC. SETUPS OP.	11	OPER	2	M^3/YR	IS			X		
RFP	774 OASIS SYSYTEM	14	OPER	60	M^3/YR	IS			X		
INEL	WED FACILITY	7	OPER	1,287	M^3/YR	IS				X	
INEL	WERF	7	OPER	1,287	M^3/YR	IS				X	
INEL	RWMC TWSTF	1	1992	2,570	M^3/YR	IS			X	X	
SRS	Z-AREA SALTSTONE	5	OPER	47,880	M^3/YR					X	NOT RCRA PERMITTED
SRS	TWF	17	1994	540	M^3/YR	X			X	X	
SRS	Y-AREA SALTSTONE	5	1993	4,536	M^3/YR	X				X	
SRS	HW/MW FACILITY	1	1993	TBD	–	X				X	
LLNL	513 SOLID. UNIT	6	OPER	246	M^3/YR	X				X	
ORNL	WHPP	17	1996	150	M^3/YR				X		REMOTE-HANDLED TRU
ORGDP	SLUDGE FIXATION FAC.	3	OPER	5,746	M^3/YR	X				X	
HANFORD	GROUT TREAT. FAC.	4	1991	12,768	M^3/YR	X				X	
HANFORD	WRAP MOD. I	16	1996	1,320	M^3/YR	X			X	X	
HANFORD	WRAP MOD. II	TBD	1999	TBD	–	X			X	X	TREATMENT PROCESS DECISION PENDING
WVDP	CEMENT SOLID. SYSTEM	7	OPER	1,681	M^3/YR	X				X	VENDOR SYSTEM; NO LONGER USED

M9-GT-0060-01

1 - solidification, unspecified (5.4.1)
2 - solidification with portland cement (5.4.1.4)
4 - solidification with portland cement, flyash and clay (5.4.1.4)
5 - solidification with portland cement, flyash and slag (5.4.1.4)
6 - in-drum solidification (5.4.1.4, 5.4.1.6)
7 - in-drum solidification with portland cement (5.4.1.4)
8 - in-drum solidification with portland cement and clay (5.4.1.4)
9 - in-drum solidification with portland cement and diatomaceous earth (5.4.1.4)
11 - in-drum solidification with portland cement and Ramcote (5.4.1.4)
14 - in-drum solidification with Environstone (5.4.1.6)
16 - sort, compact, shred and grout (5.3.1.13, 5.4.1.4)
17 - sort, shred and grout (5.3.1.13, 5.4.1.4)
34- precipitation, in-drum sludge solidification with portland cement

Figure 7.4 - Immobilization Treatment Units for DOE Low-Level and Transuranic RMW.

and Development Program; and the Hazardous Waste Compliance Technology Program. Both of these programs are funded by DOE Headquarters and managed by the Hazardous Waste Remedial Actions Program (HAZWRAP) in Oak Ridge, Tennessee. RD&D projects are conducted for the following applications: treatment/disposal of hazardous and radioactive mixed waste; waste minimization; standards and methods for site remediation/stabilization/closure; improved burial practices and waste forms; and pathways analysis. Several new technologies currently under development through these programs may have application for Rocky Flats waste streams.

A summary of RD&D projects directed towards RMW treatment technology is shown below. These projects were active during Fiscal Year (FY) 1989.

7.3.1 Waste Research and Development Projects

Supercritical Water Oxidation (Los Alamos National Laboratory) - Investigation of the oxidation of hazardous organics in supercritical water, determination of reaction kinetics, and understanding of the mechanisms and reactive species involved. Pilot-scale testing is in progress. This project entered the demonstration phase in FY 1989. Project Duration: 10/85 - 10/93.

Gas Cylinder Disposal Plant (Los Alamos National Laboratory) - Development and testing of a process for the safe disposal of the contents of unidentified or damaged gas cylinders. This project entered the demonstration phase in FY 1989. Project Duration: 10/87 - 9/91.

Treatment/Disposal of Reactive Metals (Argonne National Laboratory) - Development of a spray-burning process for converting reactive metal wastes to a glass product suitable for land disposal. This project moved from an R&D phase to pilot-scale and field demonstrations in FY 1989. Project Duration: 10/87 - 9/91

Solar Photochemical Destruction of Dilute Chemical Contaminants in Water (Sandia National Laboratory - Albuquerque) - Development of a low-temperature, high-volume process based on solar assisted photocatalytic reactions to destroy organic chemical contaminants in water effluents or groundwater. Initial tests with model compounds have proved successful. Project Duration: 10/88 - 9/91.

Detoxification of Halocarbon Streams Using Microwave-Assisted Fluid Bed Oxidation (Argonne National Laboratory) - Development of the use of microwave heating to promote detoxification reactions in waste streams containing metals and/or organic and inorganic halides and nitrates. Several waste streams or simulated waste streams have been tested on a laboratory scale using a 600W microwave heater. Conceptual design has been developed for a truck-mounted unit. Project Duration: 10/88 - 9/91.

Waste Acid Detoxification and Reclamation (Pacific Northwest Laboratory) Adaptation and demonstration of processes and process equipment that reduce the volume, quantity, and toxicity of metal-bearing waste acids generated from metal-finishing operations. Pilot-plant performance testing and demonstrations were scheduled for FY 1989 and 1990. Project Duration: 10/87 - 9/90.

Paramagnetic Separation of Wastes (Oak Ridge National Laboratory) - Development of magnetic separation of paramagnetic components from hazardous waste, recycle mixtures, or suspensions. Specifically developed for separation of uranium and other heavy metals from waste or recyclable material. This project was scheduled to enter the demonstration phase in FY 1990. Project Duration: 10/85 - 9/89.

Encapsulation Development (Brookhaven National Laboratory) - Investigation of contemporary and nontraditional encapsulation materials for their potential applications to hazardous waste. These encapsulation materials include polyethylene, sulfur cement, and polyester-styrene.

This project moved into the demonstration phase in FY 1989. Project Duration: 10/87 - 9/93.

7.3.2 Other Technology Demonstration Projects

Lead Decontamination (Idaho National Engineering Laboratory) - Demonstration of a melt-refining system to decontaminate lead. Duration: 12/88 - 6/90.

Plasma Centrifuge Reactor (DOE Component Development Integration Facility, Butte, Montana) - This is a cooperative venture between HAZWRAP and the EPA Superfund Innovative Technology Evaluation (SITE) Program. The project is to demonstrate the use of a high-temperature plasma centrifuge reactor to melt and process entire drums of organic-contaminated soils. Project Duration: 10/88 - 1/90.

Hexone Tank Treatment (Hanford Reservation) - Demonstration of technologies for the removal and disposal of organic solvents contaminated with radioactive materials. These wastes are currently stored in two deteriorating underground storage tanks. Pilot-scale tests have led to the selection of distillation as a method of decontaminating the liquid. Cleaned hexone will be stored in railroad tank cars before being incinerated. Project Duration: 5/87 -12/90.

7.4 Rocky Flats Waste Development Projects

This section discusses waste development projects ongoing at RFP that have application to RMWs. It should be noted that dates are approximate (especially those given only by fiscal year) and subject to change due to changes in priority, funding levels, or changing technology.

Cyanide Destruction - Development of a cyanide destruction process to convert spent, mixed electroplating waste into nonhazardous, low-level radioactive or nonhazardous waste for disposal. Technology also applicable to pondcrete and pond sludge.
Demonstration and implementation are scheduled to start in FY 1990.
Project Duration: 10/88 - 9/91.

Wet Oxidation of Combustibles - Development of a wet oxidation process to destroy combustible waste without incineration. Because combustible waste is the largest waste form generated, the development of this process would eliminate large quantities of mixed waste, thus reducing the risk of release both at the plant site during transportation and at the disposal site. The large cost of shipping and disposal would also be saved. Possibly applicable to FBI Oil treatment.
Laboratory scale scheduled to begin 3/90, pilot scale 7/92.
Project Duration: 3/90 - 3/94.

Microwave Melting - Development of a microwave melting process to treat sludge (LLW, TRU, and RMW), a major waste category at RFP. Cementation, currently used to immobilize sludge, adds weight and volume and results in inconsistent waste monoliths. Microwave melting reduces waste volumes up to 80% over cementation processes and produces an ideal waste form for disposal. Also applicable to soil and miscellaneous wastes.
Cold testing complete 10/90, install production unit by 9/92.
Project Duration: 1/86 - 7/94.

Solidification Development - Development of cementation and polymer encapsulation processes that will provide more durable, less leachable immobilized waste forms; processes must produce waste forms that can pass the TCLP. Some cemented forms can pass TCLP but are subject to long-term degradation and add weight and volume to the waste. Although vitrification units will eventually be used, some "hard-to-solidify" wastes may still require cementation or polymer encapsulation.

Cementation studies complete 10/90; cement and polymer solidification techniques into production by 9/92.
Project Duration: 10/87 - 9/92.

Solvent Recycle - Development of a process to permit recycle of solvents used in production. It is expected that total elimination of solvents cannot be accomplished in the next five years. Recycle of these solvents would eliminate a major waste stream. This project is to demonstrate the distillation and purification of frequently used solvents. Demonstrate bench scale process by 10/90, pilot plant by 10/91. Install full scale system by 10/93.
Project Duration: FY 90 - FY 94.

Mixed Waste Destruction - Develop a waste vitrification system and a microwave plasma destruction system. The destruction of mixed waste on plant site would eliminate the risks associated with transportation and disposal and the volume increase inherent in cementation immobilization. This technology would treat sludges and possibly roaster oxide. Installation of bench scale plasma system complete 9/91; installation demonstration glass melter complete 9/92; complete demonstration glass melting tests FY 94.
Project Duration FY 86 - FY 94.

Scrubber/Absorber Development - Develop off-gas treatment systems to remove VOCs. The use of solvents classified as hazardous materials poses the threat of release as fugitive VOCs. Air scrubber/VOC absorber systems will be tested, usage areas examined, and the developed systems strategically placed to remove VOCs. Technology applicable to all thermal waste treatment technologies.
Completion of sampling and engineering studies 9/91; complete laboratory tests 9/92; complete field demonstration 9/93.
Project Duration: 10/90 - 9/93

Combustibles and Filter Waste - Evaluation of Portland cementation and polymer encapsulation of combustibles and filter waste to determine if these treatments are suitable for immobilization of these RMW.
Complete solidification studies and testing by FY 92.
Project Duration: FY 85 - FY 92

Metal Decontamination - Evaluate the decontamination of metal waste by vibratory decontamination, electrodecontamination, and supercritical water. Vibratory decontamination uses a vibratory bed of cleaning to scour the metal, electrodecontamination uses electrochemical reduction-oxidation, and supercritical water is water at elevated temperatures and pressures.
Complete laboratory-scale vibratory study (10/90); electrodecontamination study (12/91); and supercritical water study (12/91).
Project duration: 10/90 - 12/91.

7.5 Treatment Suitability Evaluations

This section evaluates the technical capability of DOE treatment facilities to process RFP waste streams. Figures 7.7 through 7.16 indicate the feasibility of processing Rocky Flat's waste in existing and planned treatment units within the DOE complex. In constructing these figures, the applicability of each treatment unit was evaluated against treatment capability shown in Figure 7.5. The criteria shown in Figure 7.6 were developed to show the relative desirability of using the DOE treatment facilities to process Rocky Flats' wastes.

The criteria used for ranking the applicability of each treatment unit address two key factors: (1) whether the waste is amenable to the treatment technology used at the facility, and (2) the degree of modification required to safely process the waste at that facility. With the limited information available, the criteria also attempt to factor in the DOE's overall management strategy for treatment and disposal of its radioactive wastes. The ranking does not address whether the capacity of the facility is adequate to meet

FIGURE 7.5: TREATMENT CAPABILITIES OF ENERGY DEPARTMENT WASTE FACILITIES

Treatment Capabilities

H	High Level Waste
T	TRU Waste
L	Low Level Waste
R	RCRA Waste
P	TSCA Waste (PCBs)

FIGURE 7.6: CRITERIA USED TO EVALUATE THE SUITABILITY OF ENERGY DEPARTMENT WASTE FACILITIES TO PROCESS ROCKY FLATS' WASTE

Suitability Ranking	Criteria
A	The facility has the capability to treat waste that is similar to the Rocky Flats waste stream and could probably treat the Rocky Flats waste without modification.
B	The technology used at the facility is applicable to the Rocky Flats waste stream. The facility could probably treat the waste although it was originally designed for a different type of waste. Some modification of the facility, its process or its permitting would be required. Alternatively, the waste may require pretreatment.
C	The technology used at the facility is applicable to the Rocky Flats waste stream; however, the facility is designed for a significantly different waste. Extensive modification of the facility would be required. Use of this facility would be undesirable and would be incompatible with DOE waste management objectives.
Blank.	The facility's technology does not apply to the Rocky Flats waste stream.

Rocky Flats' needs and the waste processing needs of the facility's primary user. In addition, the evaluation does not consider DOT restrictions regarding shipping, nor does it consider state and/or regional resistance to hazardous waste processing. The ranking assumes that a facility with an appropriate technology could pursue a permit or make the necessary permit modifications to process the waste.

A more detailed and thorough assessment of a given facilities treatment capabilities and capacities will be made by site visits and will be reported in Treatment Plan No.1.

FIGURE 7.7: APPLICABILITY OF DOE WASTE TREATMENT FACILITIES AT LOS ALAMOS NATIONAL LABORATORY, LOS ALAMOS, NEW MEXICO

TREATMENT FACILITY	TREATMENT TECHNOLOGY	ANNUAL CAPACITY (M^3/YR)	TREATMENT CAPABILITY	ROCKY FLATS WASTES: 6.1. SOL. BYPASS SLUDGE	6.2 SOIL & CLEANUP DEBRIS	6.3 CUTOFF SLUDGE	6.4 SOLIDIFIED ORGANIC/TRU	6.5 COMBUSTIBLES & FILTERS/TRU	6.6 METAL/TRU	6.7 AQUEOUS SLUDGES/TRU	6.8 MISC. WASTE/TRU	6.9 PART./SLUDGE WASTES/TRU	6.10 ROASTER OXIDE	6.11 FBI OIL	6.12 COMBUSTIBLES	6.13 METAL	6.14 FILTERS	6.15 CEMENTED COMPOSITE CHIPS	6.16 AGID	6.17 PCB SOLIDS	6.18 PCB LIQUID	COMMENTS
PRETREATMENT PLANT	7	2	T	B	C	B		C		B	C	C	B		C	C	C	C	C			NON-RCRA ONLY
TA-50 VAC. FILTER OPER.	9	255	TL																			NO PERMIT
TA-55 Pu FACILITY	14	18	T	B		B																
WPF TA-54 (W)	17	180	T																			STORED WST ONLY
TA-50 TDF	21	5089	LRP		C	C	C	C	C		C	C	C	A	A	B	A	B		A	A	1995
TA-50 TDF	21	1010	TLRP		C	C	C	A	C		C	C	C	A	A	B	A	B		A	A	PLANNED RESTART 1990
TA-50 MICROWAVE MELTER	30	N/A	TLR	A	C	A				A	A		B						C			PROPOSED FOR 1994

7 - In drum solidification with Portland cement (5.4.1)

9 - In drum solidification with Portland cement and diatomaceous earth (5.4.1.4

14 - In drum solidification with Environstone (5.4.1.6)

17 - Sort, shred and grout (5.3.1.13, 5.4.1.4)

21 - Controlled Air Incineration (5.1.1.7)

30 - Microwave Melting (5.1.1.6)

RF-WST-A

FIGURE 7.8: APPLICABILITY OF DOE WASTE TREATMENT FACILITIES AT MOUND, MIAMISBURG, OHIO

TREATMENT FACILITY	TREATMENT TECHNOLOGY	ANNUAL CAPACITY (M^3/YR)	TREATMENT CAPABILITY	ROCKY FLATS WASTES																			
				6.1. SOL BYPASS SLUDGE	6.2 SOIL & CLEANUP DEBRIS	6.3 CUTOFF SLUDGE	6.4 SOLIDIFIED ORGANIC/TRU	6.5 COMBUSTIBLES & FILTERS/TRU	6.6 METAL/TRU	6.7 AQUEOUS SLUDGES/TRU	6.8 MISC. WASTE/TRU	6.9 PART./SLUDGE WASTES/TRU	6.10 ROASTER OXIDE	6.11 PBI OIL	6.12 COMBUSTIBLES	6.13 METAL	6.14 FILTERS	6.15 CEMENTED COMPOSITE CHIPS	6.16 ACID	6.17 PCB SOLIDS	6.18 PCB LIQUID	COMMENTS
ALPHA-CONT'D H_2O PROC FAC	7	11,800	TL	C	C	C		C		C	C	C	C		C	C	C	C	B			NO PERMIT
H-3 WTR SLD'N FACILITY	8	114	L																			NO PERMIT
CYCLONE INCINERATOR	22	0	L					C				C		B	C						B	NO LONGER OPERATING
GLASS MELTER	24	255	RL	A	C	B	C	C		C	C	C		A	A		B		A	B	B	INTERIM

7 - In Drum Solidification with Portland Cement (5.4.1.4)

8 - In Drum Solidification with Portland Cement and Clay (5.4.1.4)

22 - Cyclone Incineration (5.1.1.9)

24 - Glass Melting Incineration (5.1.1.5)

RF-WST-B

FIGURE 7.9: APPLICABILITY OF DOE WASTE TREATMENT FACILITIES AT PANTEX, AMARILLO, TEXAS

TREATMENT FACILITY	TREATMENT TECHNOLOGY	ANNUAL CAPACITY (M^3/YR)	TREATMENT CAPABILITY	ROCKY FLATS WASTES																		COMMENTS
				6.1 SOL. BYPASS SLUDGE	6.2 SOIL & CLEANUP DEBRIS	6.3 CUTOFF SLUDGE	6.4 SOLIDIFIED ORGANIC/TRU	6.5 COMBUSTIBLES & FILTERS/TRU	6.6 METAL/TRU	6.7 AQUEOUS SLUDGES/TRU	6.8 MISC. WASTE/TRU	6.9 PART./SLUDGE WASTES/TRU	6.10 ROASTER OXIDE	6.11 FBI OIL	6.12 COMBUSTIBLES	6.13 METAL	6.14 FILTERS	6.15 CEMENTED COMPOSITE CHIPS	6.16 ACID	6.17 PCB SOLIDS	6.18 PCB LIQUID	
HAZ. WASTE TREAT & PROC	21	200	5		C	C	C	C	C		C	C	C	A	A	B	A	B		B	B	PROPOSED; 1995

21 - Controlled Air Incineration (5.1.1.7)

RF-WST-C

FIGURE 7.10: APPLICABILITY OF DOE WASTE TREATMENT FACILITIES AT ROCKY FLATS, GOLDEN, COLORADO

TREATMENT FACILITY	TREATMENT TECHNOLOGY	ANNUAL CAPACITY (ft^3/YR)	TREATMENT CAPABILITY	ROCKY FLATS WASTES: 6.1 SOL BYPASS SLUDGE	6.2 SOIL & CLEANUP DEBRIS	6.3 CUTOFF SLUDGE	6.4 SOLIDIFIED ORGANIC/TRU	6.5 COMBUSTIBLES & FILTERS/TRU	6.6 METAL/TRU	6.7 AQUEOUS SLUDGES/TRU	6.8 MISC. WASTE/TRU	6.9 PART./SLUDGE WASTES/TRU	6.10 ROASTER OXIDE	6.11 FBI OIL	6.12 COMBUSTIBLES	6.13 METAL	6.14 FILTERS	6.15 CEMENTED COMPOSITE CHIPS	6.16 ACID	6.17 PCB SOLIDS	6.18 PCB LIQUID	COMMENTS
778 PONDCRETE	2	1,700	LR	C	C	C		C		C	C	C	C		C	C	C	C	B			
374 SALTCRETE	2	600	LR	C	C	C		C		C	C	C	C		C	C	C	C	B			
774 VAC. FILTER	9	120	TR	C	C	C		C		C	C	C	C		C		C	C	C			
374 VAC. FILTER	9	220	LTR	C	C	C		C		C	C	C	C		C		C	C	C			
774 SPEC SETUPS	11	2	TR	C	C	C		C		C	C	C	C		C	C	C	C	B			
774 OASIS	14	60	TR	A	B	B				A			C				C		C			
STATIONARY GRATE	20	0	T					C							A		A					NO LONGER OPERATING
F B INCINERATOR	23	0	LTR					A				B		A	A		A			A	A	ON HOLD
371 INCINERATOR	26	0	T		B	B	B	A	B		B	C	C	A	C		C	C		C	C	NO LONGER OPERATING
MICROWAVE MELTER	30	0	TLR	A	C	A				A	A		B						B			DEMONSTRATION UNIT
F B PILOT PLANT	23	0	TLRP					A				B		A	A		A			A	A	INACTIVE
GLASS MELTER	24	0	TLR	A	C	B	A	B			B	B	B		B	B		B				PILOT SCALE

2 - Solidification with Portland Cement (5.4.1.4)

9 - In Drum Solidification with Portland Cement and Diatomaceous Earth (5.4.1.4)

11 - In Drum Solidification with Portland Cement and RAMCOTE™ (5.4.1.4)

14 - In Drum Solidification with Environstone™ (5.4.1.5)

20 - Stationary Grate Incineration (5.1.1)

23 - Fluidized Bed Incineration (5.1.1.3)

24 - Glass Melting Incineration (5.1.1.5)

26 - Rotary Kiln Incineration (5.1.1.1)

30 - Microwave Melting (5.1.1.6)

RF-WST-D

FIGURE 7.11: APPLICABILITY OF DOE WASTE TREATMENT FACILITIES AT IDAHO NATIONAL ENGINEERING LABORATORY, IDAHO FALLS, IDAHO

TREATMENT FACILITY	TREATMENT TECHNOLOGY	ANNUAL CAPACITY (m^3/YR)	TREATMENT CAPABILITY	ROCKY FLATS WASTES: 6.1 SOL. BYPASS SLUDGE	6.2 SOIL & CLEANUP DEBRIS	6.3 CUTOFF SLUDGE	6.4 SOLIDIFIED ORGANIC/TRU	6.5 COMBUSTIBLES & FILTERS/TRU	6.6 METAL/TRU	6.7 AQUEOUS SLUDGES/TRU	6.8 MISC. WASTE/TRU	6.9 PART./SLUDGE WASTES/TRU	6.10 ROASTER OXIDE	6.11 FBI OIL	6.12 COMBUSTIBLES	6.13 METAL	6.14 FILTERS	6.15 CEMENTED COMPOSITE CHIPS	6.16 ACID	6.17 PCB SOLIDS	6.18 PCB LIQUID	COMMENTS
WED FACILITY	7	1237	LR	B	A	B		C		C	C	C	A		C	C	C	C	B				
WERF	7	1237	LR	B	A	B		C		C	C	C	A		C	C	C	C	B				
WERF	21	5449	LR		C	C	C	C	C		C	C	C	A	B	B	A	B					
PREPP	26	5449	TLR	B	B	B	B	A	A		A	B	C	A	B	B	A	B		B	B		1992
NWCF	27	3349	HR		C	C	C	C	C		C	C	C	C	C	C	C	C		C	C		
WASTE IMMOBILIZATION FACILITY	28	1000	HR																				2012
PLASMA ARC	33	5449	TLR	A	A	A	A	A	A	B	B	A	A	C	A	A	A	A	B	B	B		1995
TWSTF	1	2570	TLR	A	A	A		B		A	B	B	A		B	B	C	B	B				1992
EVAPORATION	31	185K	L																				TBD; UNDER EVAL.
ICPP EVAPORATOR	31	15K	LR																				
HEPA FILTER LEACH TANK	32	161	HR						C														1990

1 - Solidification (5.4.1)
7 - In Drum Solidification with Portland Cement (5.4.1.4)
21 - Controlled Air Incineration (5.1.1.7)
26 - Rotary Kiln Incineration (5.1.1.1)
27 - Calcination (5.3.1.2)
28 - Glass-Ceramic Process (5.5.1.1)
31 - Evaporation (5.3.1.2, 5.2.1.7, 5.3.1.3, 5.3.1.11, 5.3.1.7, 5.3.1.6)
32 - Leaching System (5.2.1.10)
33 - Plasma Arc Incineration (5.1.1.12)

RF-WST-E

FIGURE 7.12: APPLICABILITY OF DOE WASTE TREATMENT FACILITIES AT WEST VALLEY DEMONSTRATION PROJECT, WEST VALLEY, NY

TREATMENT FACILITY	TREATMENT TECHNOLOGY	ANNUAL CAPACITY (m^3/YR)	TREATMENT CAPABILITY	ROCKY FLATS WASTES: 6.1 SOL BYPASS SLUDGE	6.2 SOIL & CLEANUP DEBRIS	6.3 CUTOFF SLUDGE	6.4 SOLIDIFIED ORGANIC/TRU	6.5 COMBUSTIBLES & FILTERS/TRU	6.6 METAL/TRU	6.7 AQUEOUS SLUDGES/TRU	6.8 MISC. WASTE/TRU	6.9 PART./SLUDGE WASTES/TRU	6.10 ROASTER OXIDE	6.11 FBI OIL	6.12 COMBUSTIBLES	6.13 METAL	6.14 FILTERS	6.15 CEMENTED COMPOSITE CHIPS	6.16 ACID	6.17 PCB SOLIDS	6.18 PCB LIQUID	COMMENTS
CEMENTED SOLID SYSTEM	7	1681	LR	B	B	B		C		C	C	C	B		C	B	B	C	C			
VITRIFICATION SYSTEM	29	62	MR	C	C	C	C	C		C	C	C		C	C		C		C	C	C	1993

7 - In Drum Solidification with Portland Cement (5.4.1.4)

29 - Vitrification (5.1.1.5)

FIGURE 7.13: APPLICABILITY OF DOE WASTE TREATMENT FACILITIES AT SAVANNAH RIVER SITE, AIKEN, SC

TREATMENT FACILITY	TREATMENT TECHNOLOGY	ANNUAL CAPACITY (M^3/YR)	TREATMENT CAPABILITY	ROCKY FLATS WASTES																			
				6.1 SOL BYPASS SLUDGE	6.2 SOIL & CLEANUP DEBRIS	6.3 CUTOFF SLUDGE	6.4 SOLIDIFIED ORGANIC/TRU	6.5 COMBUSTIBLES & FILTERS/TRU	6.6 METAL/TRU	6.7 AQUEOUS SLUDGES/TRU	6.8 MISC. WASTE/TRU	6.9 PART./SLUDGE WASTES/TRU	6.10 ROASTER OXIDE	6.11 PBI OIL	6.12 COMBUSTIBLES	6.13 METAL	6.14 FILTERS	6.15 CEMENTED COMPOSITE CHIPS	6.16 ACID	6.17 PCB SOLIDS	6.18 PCB LIQUID	COMMENTS
Z AREA SALTSTONE	5	45K	L	B	C	B		C		C	C	C	B		C	B	B	B	B			1989
ETF	15	396K	LR																B			1988
TWF	17	540	-	B	B	B		A		A	B	A	B		A	A	A	A	B			1994
DWPF	29	1K	M	C	C	C	C	C		C	C	C		C			C		C	C	C	1992
Y-AREA SALTSTONE	5	4K	LR	B	C	B		C		C	C	C	B		C	B	B	B	B			1993
CIF	26	45K	LR		A	A	C	C	C		C	C	C	A	A	B	A	B		B	B	1992
HM/MW FAC.	1	TBD	LR	B	B	B		C		C	C	C	B		B	A	A	A	B			1993
PWI	21	0	L		A	A	C	C	C		C	B	B	C	C	C	C	C		C	C	INACTIVE
BETA-GAMMA INCINERATOR	21	0	T		A	A	C	C	C		C	B	B	C	C	C	C	C		C	C	

1 - Solidification (5.4.1)

5 - Solidification with Portland Cement, Flyash and Slag (5.4.1.4)

15 - Carbon adsorption, reverse osmosis, ion exchange evaporation (5.3.1.11, 5.3.1.7, 5.3.1.6, 5.3.1.2)

17 - Sort, shred and Grout (5.3.1.13, 5.4.1.4)

21 - Controlled Air Incineration (5.1.1.7)

26 - Rotary Kiln Incineration (5.1.1.1)

29 - Vitrification (5.1.1.5)

RF-WST-G

FIGURE 7.14: APPLICABILITY OF DOE WASTE TREATMENT FACILITIES AT OAK RIDGE FACILITIES, OAK RIDGE, TN

				ROCKY FLATS WASTES																			
TREATMENT FACILITY	TREATMENT TECHNOLOGY	ANNUAL CAPACITY (m^3/YR)	TREATMENT CAPABILITY	6.1 SOL BYPASS SLUDGE	6.2 SOIL & CLEANUP DEBRIS	6.3 CUTOFF SLUDGE	6.4 SOLIDIFIED ORGANIC/TRU	6.5 COMBUSTIBLES & FILTERS/TRU	6.6 METAL/TRU	6.7 AQUEOUS SLUDGES/TRU	6.8 MISC. WASTE/TRU	6.9 PART./SLUDGE WASTES/TRU	6.10 ROASTER OXIDE	6.11 PBI OIL	6.12 COMBUSTIBLES	6.13 METAL	6.14 FILTERS	6.15 CEMENTED COMPOSITE CHIPS	6.16 ACID	6.17 PCB SOLIDS	6.18 PCB LIQUID	COMMENTS
WHPP	17	159	T	C	C	C		B		B	B	B	B		C	C	C	C	C				1996
TSCA INCINERATOR	26	6200	LRP		A	A	C	C	C		C	C	C	C	A	A	A	A	B		A	A	1989
SLUDGE FIXATION FACILITY	3	5748	LR	B	B	B		C		C	C	C	B		B	C	B	B	C				

3 - Solidification with Portland Cement and Flyash (5.4.1.4)

17 - Sort, Shred and Grout)5.3.1.13, 5.4.1.4)

26 - Rotary Kiln Incineration (5.1.1.1)

FIGURE 7.15: APPLICABILITY OF DOE WASTE TREATMENT FACILITIES AT LAWRENCE LIVERMORE NATIONAL LABORATORIES, LIVERMORE, CA

TREATMENT FACILITY	TREATMENT TECHNOLOGY	ANNUAL CAPACITY (M^3/YR)	TREATMENT CAPABILITY	ROCKY FLATS WASTES																				
				6.1 SOL BYPASS SLUDGE	6.2 SOIL & CLEANUP DEBRIS	6.3 CUTOFF SLUDGE	6.4 SOLIDIFIED ORGANIC/TRU	6.5 COMBUSTIBLES & FILTERS/TRU	6.6 METAL/TRU	6.7 AQUEOUS SLUDGES/TRU	6.8 MISC. WASTE/TRU	6.9 PART./SLUDGE WASTES/TRU	6.10 ROASTER OXIDE	6.11 FBI OIL	6.12 COMBUSTIBLES	6.13 METAL	6.14 FILTERS	6.15 CEMENTED COMPOSITE CHIPS	6.16 ACID	6.17 PCB SOLIDS	6.18 PCB LIQUID	COMMENTS
513 SOLIDIFICATION UNIT	6	181	LR	B	B	B		B		B	B	B	B		B	B	B	B	B				
CA INCINERATOR	21	72	LR		C	C	B	B	C			B	C	A	A	C	A	C		B	B		NO RCRA 1995 MEDICAL
DWTF	26	170	LR		C	C	B	B	C		B	B	A	A	A	A	A	A		B	B		1996

6 - In Drum Solidification (5.4.1.4, 5.4.1.6)

21 - Controlled Air Incineration (5.1.1.7)

26 - Rotary Kiln Incineration (5.1.1.1)

FIGURE 7.16: APPLICABILITY OF DOE WASTE TREATMENT FACILITIES AT HANFORD, WA

TREATMENT FACILITY	TREATMENT TECHNOLOGY	ANNUAL CAPACITY (M^3/YR)	TREATMENT CAPABILITY	ROCKY FLATS WASTES: 6.1 SOL BYPASS SLUDGE	6.2 SOIL & CLEANUP DEBRIS	6.3 CUTOFF SLUDGE	6.4 SOLIDIFIED ORGANIC/TRU	6.5 COMBUSTIBLES & FILTERS/TRU	6.6 METAL/TRU	6.7 AQUEOUS SLUDGES/TRU	6.8 MISC. WASTE/TRU	6.9 PART./SLUDGE WASTES/TRU	6.10 ROASTER OXIDE	6.11 FEI OIL	6.12 COMBUSTIBLES	6.13 METAL	6.14 FILTERS	6.15 CEMENTED COMPOSITE CHIPS	6.16 ACID	6.17 PCB SOLIDS	6.18 PCB LIQUID	COMMENTS
GROUT TREATMENT FACILITY	4	13K	LR	B	C	B		C		C	C	C	C		C	C	B	B	B			1991
WRAP MOD I	16	1320	TLR	A	A	A		A		A	A	A	A		A	A	A	B	A	B		1996
WRAP MOD II	TBD	2890	TLR																			NOT DEFINED 1999
HWVP	29	3785	HR	C	C	C	C	C		C	C	C		C	C		C		C	C	C	1991
HEXONE TANKS	34,19	809	LTR																			1991
303-M OXIDE	25	6	LR																			PYRO METALS ONLY

4 - Solidification with Portland Cement, Flyash and Clay (5.4.1.4)

16 - Sort, compact, shred and grout (5.3.1.13, 5.4.1.4)

18 - Distillation (5.3.1.9)

19 - Incineration (5.1.1)

25 - Roasting (5.1.1.17)

29 - Vitrification (5.1.1.5)

RF-WSR-J

8.0 COMMERCIAL TREATMENT FACILITIES

No commercial facilities are currently available that have a permit to treat mixed waste.

A facility at Oak Ridge, Tennessee, operated by SEG (Scientific Ecology Group), has a permit for low level radioactive waste, but not for mixed waste. A permit for mixed waste is being sought.

9.0 SUMMARY AND CONCLUSIONS

This report - Treatment Report No.1 - is one of eleven reports to be prepared in accordance with the FFCA. The purpose of the report is to describe waste processing technologies that might be used to convert 18 mixed wastes identified in the Storage Report from land disposal-prohibited wastes to LLW, TRU waste, or mixed waste that will meet LDR requirements.

Over 50 possible treatment technologies were described that might treat these wastes to permit land disposal. Any technology that theoretically might work was included; many are of doubtful value because of their complexity and because alternatives exist that appear more practical.

Of the prospective thermal technologies, incineration appears to be one of the best demonstrated and is well-advanced. Vitrification is also a multiple-use treatment method, and one that would provide a monolithic or granular waste of low leachability. The plasma arc furnace was the only treatment technology possibly applicable to all the waste, but it is still in the developmental stage.

Chemical treatments were limited to specific wastes with little multiple use except for biodegradation, which will probably ultimately prove to have little application to these wastes.

Promising physical methods include volatilization, air stripping, and steam stripping. Supercritical fluid and solvent extraction methods may be of use but developmental work would be required for these unusual applications.

Immobilization with lime-fly ash pozzolan and Portland cement is a well-developed technology, but organic removal will be required before cementation. Polymer encapsulation is a promising technique that may prove to contain both EP Toxic metals and HOCs, and development of this technology should proceed.

It is not the purpose of this report to pass judgment on the listed technologies. Technology ranking will be established in Treatment Plan No.1, along with development tasks and schedules perceived to be necessary to demonstrate technology. Treatment Plan No.1 will also apply the two ranking systems, short and long term, briefly discussed in this report. The short term ranking will favor those technologies that are well-developed, effective, and can be quickly implemented to enable RFP to achieve compliance with the law. The long term ranking will favor technologies that, even though they may require development, have the potential of reducing waste volumes, decreasing leachability, etc., in the long term. This effort parallels other efforts being made under FFCA for Waste Minimization.

One very important conclusion from this report is that waste characterization of many large volume wastes will be required before waste treatment can be approached intelligently.

Additional information is being obtained. Part of this will come from a continuing literature search as well a visits to various sites, but part will be provided in the "National Report on Prohibited Waste and Treatment Options," to be issued by DOE Headquarters on January 17, 1990. Most of these DOE facilities process waste from their site only. Whether there is excess capacity for processing of other wastes within the DOE complex will have to be determined. Transportation concerns and legal limitations on shipping, receiving, and processing wastes at DOE sites in states other than the host state to the generating facility will also be explored.

No commercial facility is currently permitted to treat mixed wastes.

Finally, not all LDR wastes at RFP are included in this report. Treatment Report No.2 and Treatment Plan No.2 will provide the same information for wastes not identified in the Storage Report that are subsequently determined to be prohibited waste; these wastes will be defined in the Land Disposal Restrictions Determination Report, to be issued by Waste Operations.

APPENDIX

External Review Board Members

A five member External Review Board was established to review and evaluate the information prepared for this report. Following is a list of the members of this Board, along with a summary of their areas of experience and expertise.

PETER COLOMBO is an Associate Chemist in the Department of Nuclear Energy at Brookhaven National Laboratory. He is currently Manager for Nuclear Waste Research and a Principle Investigator for DOE and EPA programs.

Mr. Colombo has been at Brookhaven since 1951 and is a member of the Scientific Staff. His past experience includes studies dealing with the separation of radionuclides from fuel reprocessing waste, radiation chemistry of polymers and other organic materials, and the development of polymer-impregnated concrete for fuel-cycle and non-fuel cycle applications.

In 1971, Mr. Colombo established a Nuclear Waste Research Group and managed programs for the Nuclear Regulatory Commission concerned with the development and evaluation of solidified radioactive wastes for the commercially operated nuclear power plants. He also conducted isotope migration studies at the commercially operated low-level radioactive waste disposal sites and assisted NRC with development of waste form performance criteria and testing methods in accordance with 10 CFR 61.

Between 1974 and 1980, Mr. Colombo conducted programs for DOE on tritium storage development and on the solidification of fuel reprocessing wastes. Since 1980 he has been involved with programs for the DOE National Low-Level Waste Management Program with emphasis on the development of solidification systems for DOE defense "problem" waste streams, development of an accelerated

leach test, and development of waste form performance criteria in compliance with DOE Order 5820.2A

For the past four years Mr. Colombo has been involved with the Hazardous Waste Remedial Actions Program for the development of new and innovative encapsulation processes for mixed and chemical hazardous waste. EPA studies since 1976 include the retrieval and evaluation of radioactive waste packages from Atlantic and Pacific Ocean dump sites to determine the fate of the packages in ocean environments during the time that the United States practiced ocean dumping (1946-1970). Other studies for EPA involved the development of waste form performance criteria and testing methods for ocean disposal of low-level radioactive waste and a study of disposal options for FUSRAP.

RONALD R. H. COHEN is an Assistant Professor in the Department of Environment Sciences and Engineering Ecology at the Colorado School of Mines, Golden, Colorado. He has a BA in Biology from Temple University and a PhD in Environmental Sciences from the University of Virginia.

Prior to joining the faculty at the Colorado School of Mines, Dr. Cohen was project chief for the U. S. Geological Survey working on the Potomac River Quality Assessment and Modeling Principles Project. He is currently a technical consultant for the Colorado Water Quality Commission.

Dr. Cohen's research interest encompass the fields of hydrology, aquatic ecology, stream and estuary chemistry, phytoplankton ecology, and transport modeling. In this latter area, his current work involves modeling and studying trace metal transport in an acid mine drainage-impacted stream. In another project he is determining the amount of plutonium 239 and 240 and cesium 137 in Colorado Front Range lake sediments and using lead 210 to measure sedimentation rates in the same lake.

Other projects include minimizing ground water sampling needs, the effect of phytoplankton respiration on carbon dioxide in the atmosphere, and

hydrogeochemistry of an artificial wetland used for acid mine draining treatment. He has also developed the curriculum for a 12-week course in hazardous waste management.

MARK A. GERBER is a Senior Research Engineer in the Chemical Process Development Section, Materials and Chemical Applications Department, Pacific Northwest Laboratory. He has a BS and MS in Chemical Engineering from the University of Idaho.

Mr. Gerber has broad experience in hazardous waste treatment and hydrocarbon fuel technologies. His experience in hazardous waste has encompassed planning for the development and evaluation of remedial action alternatives for both hazardous and mixed waste sites as well as the identification and evaluation of advanced technologies for the treatment and disposal of nuclear fuel reprocessing wastes. His hydrocarbon fuels experience has included technical management of biomass thermochemical conversion research, energy systems analysis including biomass gasification, pyrolysis, combustion research, and waste stream utilization.

In the area of hazardous wastes, Mr. Gerber assisted in the preparation of site remediation RI/FS work plans for three operable units at the Hanford Site. He also provided technical support to DOE Environmental Safety and Health groups including the review of both RI/FS plans and proposed remedial actions for two DOE-managed sites. In addition, he has provided RI/FS technical support to a private client including the review of proposed remedial actions involving incineration technologies, review of a proposed plan for conducting a groundwater extraction demonstration, and assistance in the preparation of a quality assurance plan for that demonstration.

Mr. Gerber was involved in the Assessment of Pretreatment Alternatives for Hanford Single-shell Tank Wastes. He conducted research to identify and evaluate the suitability of existing and advanced technologies for pretreating mixed wastes currently stored in single shell tanks at the Hanford Site.

The Northwest Hazardous Waste Research Development and Demonstration Center is managed for DOE by the Pacific Northwest Laboratory. Mr. Gerber was responsible for implementing research and planning activities for the Center during the first years of operation. This including managing state-of-the-art studies for hazardous waste technologies.

JOANN SILVERSTEIN is an Associate Professor in the Department of Civil, Environmental, and Architectural Engineering at the University of Colorado, Boulder. Her BS, MS, and PhD degrees in Civil Engineering are from the University of California at Davis. She also is a registered professional engineer.

Dr. Silverstein's research interests are focused on the application of biological processes in water, wastewater, and sludge treatment. Current projects include: biodegradation of substituted phenolic compounds by activated sludge, especially the role of secondary substrates on degradation kinetics; biological denitrification of potable water supplies; nitrification of wastewater (for ammonia removal) in biofilm processes; composting of sludge; and development of computer models for waste treatment processes, specifically secondary clarifier analysis, biofilm nitrification and semi-batch activated sludge processes. Sponsors of Dr. Silverstein's research projects include the National Science Foundation, the City of Longmont, Colorado, and the Adolph Coors Co.

At the graduate level, Dr. Silverstein teaches courses in advanced water and wastewater treatment, hazardous and industrial waste management, and environmental engineering chemistry.

VICTOR F. YESAVAGE is a Professor of Chemical Engineering and Petroleum at the Colorado School of Mines, Golden, Colorado. He has a BS in Chemical Engineering from Cooper Union and an MS and PhD, also in Chemical Engineering, from the University of Michigan.

At the Colorado School of Mines, Dr. Yesavage has taught a wide range of under graduate courses in the chemical engineering department. At the graduate level he has taught applied mathematics, chemical reaction engineering, numerical methods, heat transfer, thermodynamics, and environmental engineering. In addition, he has been involved in a continuing education course on shale oil in which he has taught sections on shale oil processing and environmental considerations.

Dr. Yesavage has directed contract research for DOE, National Science Foundation, International Coal Refining Co., National Bureau of Standards, Phillips Petroleum, and IBM. The research areas of his graduate students have included shale oil processing, dry scrubbing of sulfur dioxide from flue gas using sodium bicarbonate, aqueous phase adsorption of polar organic compounds on activated carbon, and flash fusion of xerographic toner.